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10. Supplementary Notes Translation of "Zweites Programm Energieforschung und Energietechnologien", German Ministry for Research and Technology, Bonn, West Germany, Report, 1982, pp. i-iv, 1-122.		
11. Abstract The Second Major Energy Research and Development program sponsored by the West German Federal Ministry of Research and Technology is described. A discussion of renewable and non-renewable energy resources is presented, including nuclear technology and future energy sources, like fusion. The current status and outlook for future progress are given.		

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Abbreviations

AGF	Working union of large research facilities
ANL	Argonne National Laboratory
Arge HTR	Working Union on the HTR-project
ASA	"Applied System Analysis" (a project of the AGF)
ASDEX	A Tokamak device of the IPP
AVR	Working union on test-reactors GmbH
BAM	Federal Agency for Material Testing, Berlin
BGR	Federal Agency for Geosciences and Raw Materials, Hannover
BIP	Gross national product
BMBAu	Federal Ministry for regional planning, construction and city planning, Bonn
BMFT	Federal Ministry for research and technology
BMI	Federal Ministry of the Interior
BML	Federal Ministry for nutrition, agriculture and forestry
BMWi	Federal Ministry for Commerce
BMV	Federal Ministry of Transportation
BMZ	Federal Ministry for Economic Cooperation
BNFL	British Nuclear Fuels Ltd.
BSP	Gross social product
CEA	French Atomic energy agency (Commissariat à l'Energie Atomique)
CO ₂	Carbon dioxide
DBE	German Union for Building and Operation of End-stores
DFVLR	German Research and Testing Agency for air and Space Travel
DGF	German Research Union
DWK	German Union for Nuclear Fuels Reprocessing
DWR	Pressurized water reactor
ECE	Economic Commission for Europe of the United Nations
EdF	Electricité de France (French State electricity company)
EDV	Electronic data processing
EEV	End-energy consumption
EG	European Economic Community
EGKS	European Coal and Steel Union
ENEL	Ente Nazionale per l'Energia Elettrica (Italian State electricity company)
ESK	European Fast-breeder Nuclear Power Plant Union, mbH

EURATOM	European Atomic Energy Society
EVA	Single fission-tube test facility of the KFA, Jülich
EVU	Energy supply company (utility)
FEL	Research, Development and Demonstration
FuE	Research and Development (R&D)
GAST	Gas-cooled solar tower power plant
GFS	Joint Research Center of the EG in Ispra
GKSS	GKSS Research Center at Geesthacht GmbH (formerly Union for Nuclear Energy use in Shipbuilding and Ocean Transport mbH)
GROWIAN	Large wind energy facility
GRS	Company for Reactor Safety mbH, Cologne
GSF	Company for Radiation and Environmental Research mbH in Neuherberg by Munich
GSI	Company for Heavy ion Research
GUSI	Geesthacht Underwater simulation facility
HDR	Hot-steam reactor at Grosswelzheim
HKG	High temperature nuclear power plant, GmbH
HMI	Hahn-Meitner Institute for nuclear research GmbH in Berlin
HTR	High-temperature reactor
IAEA	International Atomic Energy Agency
IAEO	International Atomic Energy Organization in Vienna
IEA	International Energy Agency of the OECD in Paris
IIASA	International Institute for Applied System analysis in Laxenburg by Vienna
INB	International Sodium Breeder Reactor Building Company mbH
INFCE	International Evaluation of the Nuclear Fuel Cycle (1977-1980)
IPP	Max-Planck Institute for Plasma Physics in Garching by Munich
IUREP	International Uranium Resources Evaluation Project
J	Joule
jato	tons per year
JET	Joint European Torus (fusion experiment of the EG)
JUPITER	Jülich pilot plant for thorium element reprocessing
KFA	Nuclear research facility, Jülich GmbH
KFK	Nuclear research facility, Karlsruhe GmbH
kW (KW)	Kilowatt
LOBI	Loop of blowdown Investigation
LOFT	Loss of fluid test
LWR	Light water reactor
MPG	Max-Planck Society

MW _e	Megawatts of electrical power
MW _{th}	Megawatts of thermal power
NCS 80	Nuclear Container Ship with 80 WPS
NEA	Nuclear Energy Agency; nuclear energy agency of the OECD
NERSA	Centrale Nucléaire Européenne Rapide S.A.
NET	Next European Torus (a future fusion experiment of the EG)
NFE	Nuclear remote energy
NOT-design	New Austrian Tunneling method
NRW	North-Rhine Westfalia
OECD	Organization for economic cooperation and development in Paris
OTEC	Ocean Thermal Energy Conversion
PEV	Primary energy consumption
PJ	Peta Joule (10^{15} Joules = 0.034 million tons of SKE)
PNP	Project on nuclear process heat
PTB	Federal Physical-Technical Agency
Pu	Plutonium
Purex	Reprocessing process for LWR fuel elements
PWA	Project on "Reprocessing and Waste Treatment"
RAG	Ruhrkohle AG
RBW	Rheinische Braunkohlenwerke AG
RWE	Rheinisch-Westfälisches Elektrizitätswerk AG
SBK	Fast-breeder nuclear power plant company mbH
SBR	Fast breeder reactor
SKE	Hard coal unit (a unit for energy; average heating value of one ton of hard coal)
SNG	Substitute natural gas (synthetic natural gas)
SNR	Nuclear power plant with fast, sodium-cooled breeder reactor
SSPS	Solar Satellite Power Station
TEG	Partial Construction Approval (within the licensing procedure prescribed by the atomic energy law)
TEXTOR	Tokamak test facility of the KFA Jülich
THTR	Thorium high-temperature reactor
TMI	Three Mile Island (reactor site near Harrisburg, PA)
Tokamak	A test facility for nuclear fusion experiments (with magnetic plasma enclosure)
²³⁵ U	Fissionable uranium isotope (makes up about 0.7% of natural uranium)

^{238}U	Most common uranium isotope
U_3O_8	Uranium oxide
UF_6	Uranium hexafluoride
URANIT	Uranium isotope separating company mbH
URENCO	Uranium Enrichment Company
URG	United Reprocessors GmbH
UTA	Uranium Separating Unit (measured in jato)
VN	United Nations
WAK	Karlsruhe reprocessing facility
WPS	Shaft horsepower
ZIP	Future investment program

1. Introduction

1.1 Program Goals

The research and technology policy of the Federal Government of Germany should contribute toward maintaining and improving the living and working conditions of our citizens and the efficiency and competitiveness of our economy.

Because almost all areas of our life--from industrial and agricultural production, the service industries to individual lifestyle and leisure configurations--are linked with the use of energy, it is a particularly important and demanding task to meet the demand for energy under the best-possible economic and ecological conditions.

The solution to this problem has not become easier in recent years. Continuing supply uncertainties of energy imports, especially of the most important energy source--petroleum--the greater sensitivity of our economy to economic stress due to energy imports, and above all, the growing requirements for environmental protection are important problems. Under consideration of limited domestic energy potentials, new technologies can provide contributions toward solving the problems, both for a more effective use of energy and for the discovery of new energy sources and for the avoidance of pollution. In addition, research and technology must contribute toward solving the energy problem of the developing countries, because their economic evolution is decisively affected by the availability of low-cost energy. From this there results a demand for suitable energy technologies for the Third World and for those energy technologies for industrial countries, which do not further constrict the supply potentials of developing countries.

In order that the research and technology policy can make the greatest-possible contribution toward solving these problems, the actions of the second Energy Research Program are oriented toward the following goals:

- medium- and long-term securing of the energy supply
- acquisition and rational use of energy at favorable economic costs
- proper and timely consideration of the needs for environmental protection, the conservative use of natural resources and protection of the populace and of employees against dangers in energy conversion and use
- enhancement of the technological effectiveness to maintain economic competitiveness in energy technology.

The program thus supports the energy policy of the Federal Government as presented in the Third Continuation of the Energy Program of November 1981. It is also in close relation to other programs of the Federal Government, especially in the areas of Environment and Raw-materials policy.

With the funding for the development of new energy technologies by the state and private industry and their successful introduction and broad use, jobs will be secured and new ones created.

In agreement with the main thrusts of energy policy of the Federal Government, the work of research, development and demonstration encompasses the following areas of the energy sphere:

- rational and conservative energy use
- coal and other fossil fuels
- renewable energy sources
- nuclear fuel cycle and reactor safety for light-water reactors
- advanced reactors
- controlled nuclear fusion.

The energy-research policy must be aimed primarily toward "robust" development lines, that is, toward those needed equally for a number of different, future situations and frame-conditions of energy supply.

1.2 Starting Situation

The foreseeable development of national and world-wide energy supply requires a thorough restructuring of our energy supply and useage, e.g. through the reduction of the oil-fraction. This structural change should be supported by the development of new energy technologies. Thus also in R & D, numerous criteria should be noted, as have been formulated e.g. by the Enquete Commission on "Future Nuclear Energy Policy" of the 8th German Bundestag for Energy Policy. A responsible weighing of advantages and disadvantages of various energy systems requires that questions of environment and social compatibility, reliability of supply and international compatibility be taken increasingly into account, in addition to the economic aspect.

The development of complex, new technologies until their economical use, often takes a very long time. The level and structure of the energy demand however, cannot be accurately predicted, even for relatively short periods of time, because many parameters, e.g. consumer behavior, price-relations, external-economic data, change over time. Thus, in spite of all efforts toward a secured basis for the research planning, there still remains considerable uncertainty with regard to the size and timing of the demand for new technologies. Therefore, the actions of the program cannot be delayed to some indefinite future expectations. Rather, they must be of such broad scope that they expand the freedom of future energy-policy decisions in order to take into account the various, possible developments. The significance of the energy problem justifies a broad application which does not exclude any promising development trend. However, with increasing progress and knowledge, the effort in the individual research areas must be tailored increasingly to the obtained results and clearly recognizable expectations. In case of needed corrections of course, it must be taken into account that the erection and dismantling of high-performance research capacities are not possible in short time-spans.

Theoretically, there is an almost unlimited supply of available energy; but there is often a very great difference between the theoretically possible and the practically useful potentials. It is the task of energy research to identify useable potentials for energy supply and to develop known potentials for energy conservation and energy production for its economic use while maintaining the named boundary conditions.

1.2.1 Energy-Management Situation

The Federal Republic of Germany (FRG) had a primary energy consumption in 1981 of 371.0 Million tons of hard-coal units which was composed as follows (see also fig. 1):

- 44.5% petroleum
- 21.2% hard coal (bituminous coal)
- 10.8% soft coal (brown coal or lignite)
- 15.9% natural gas
- 4.6% nuclear energy
- 3.0% hydropower and other energy sources

95% of the petroleum and around 60% of the natural gas had to be imported. The high import-dependence, especially on petroleum, means a constant risk to our energy supply. In addition, the massively rising expenditures in recent years for energy imports (1981 net, 75 billion DM corresponding to about 20% of the value of German exports) led to severe losses in overall economic growth and well-being. These developments have made clear that the reduction of the oil percentage of the energy consumption and the structural adaptation of the national economy to the world-wide, changed energy situation are of great importance for the future effectiveness and competitiveness. The stepwise exhaustion of other, existing conservation potentials and a greater useage of all energy sources which replace oil or whose use is economically, ecologically and socially feasible, increases the supply reliability and enhances the national economy. An important goal of research policy is to accelerate this process through the development of economical, new energy technologies.

The primary energy consumption in the FRG has increased only slightly on average, over the last 10 years; in 1980 and 1981, it actually declined. It is particularly important that as a result of the conservative and rational useage of energy, the close linkage between economic growth and energy consumption has been clearly reduced. For instance, from 1973 to 1981, the primary energy consumption dropped by 2%, whereas the real, gross national product increased by a total 17.1%. Even though the growth in energy consumption has been considerably lower than was formerly predicted, and even though the energy market-situation has stabilized at present for various reasons, one should not be deceived about the continuing, politically-induced supply risks and the longer-term energy problems. In spite of the stagnant economic growth and the effective efforts for saving energy, it can be assumed that the energy consumption by industrial countries will continue to increase, even though less than in the past. The energy demand of the Third World will probably grow

much faster, so that one has to assume a long-term tight, world-wide supply situation.

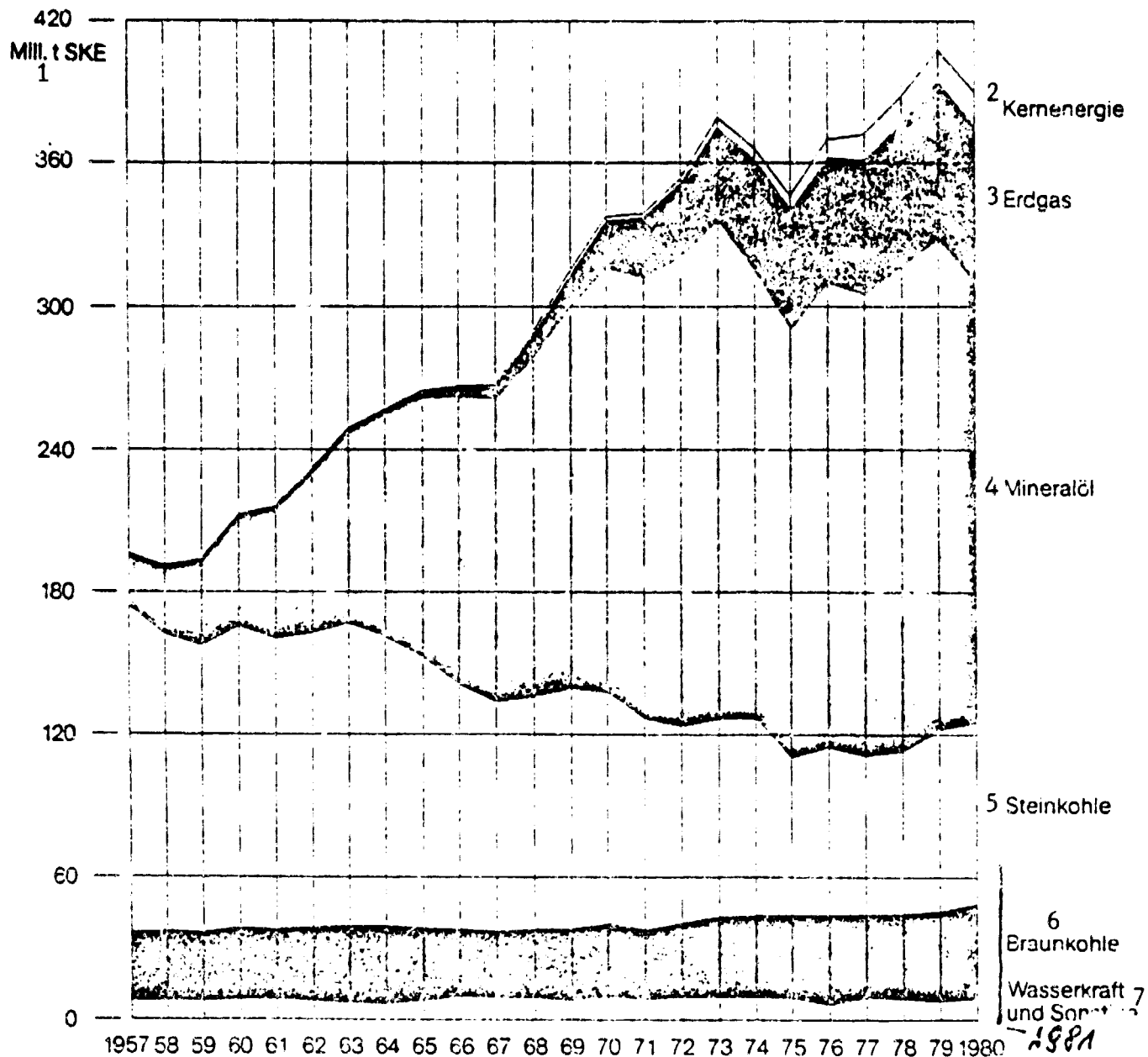


Fig. 1: Development and Composition of the Primary Energy Consumption of the FRG.

Key: 1-million tons of hard-coal units 2-nuclear energy 3-natural gas 4-petroleum 5-hard coal 6-soft coal 7-hydropower and other sources

As a result of the efforts toward substitution and in particular, large savings in petroleum products, a turn in the trend is discernable: The constantly rising percentage of petroleum of the primary energy supply in the 1950s and 1960s reached its highest level in 1973 of 55.2% and has retreated by 1981 to 44.5%. This approximately

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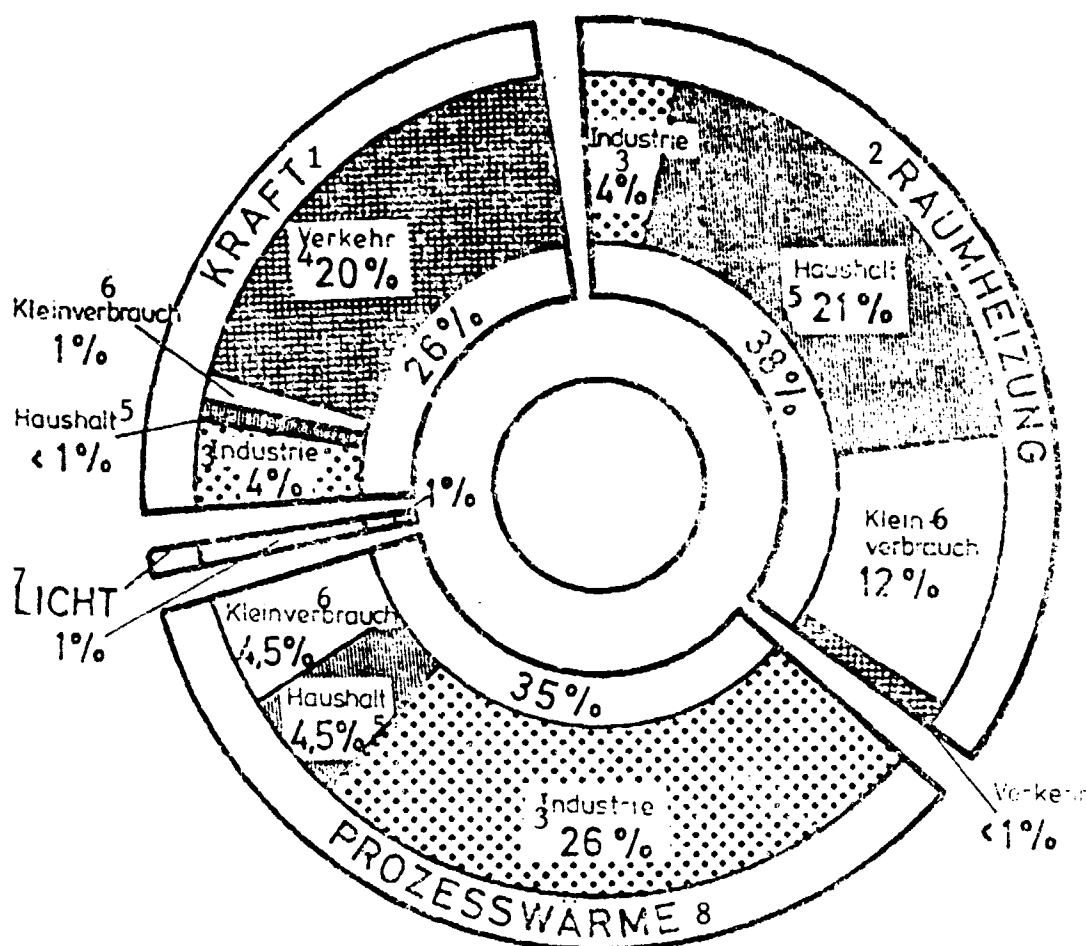


Fig. 2: Energy Consumption Breakdown (status: 1979)
(Source: Forschungsstelle fuer Energietechnik, Munich)

Key: 1-power 2-space heating 3-industry 4-transportation 5-household
6-small consumers 7-light 8-process heat

corresponds to the value of 1966 (the absolute consumption rose from 1966 to 1981 from 122 to 165 million tons of hard coal units due to the increased consumption of total primary energy).

Far more important than the absolute consumption for the alignment of energy research, is the structure of the energy demand. The great demand for low-temperature heat, especially for space heating, is shown in fig. 2: The end-energy consumption for households and small consumers is made up to about 80% by space heating, which in turn is ca. 60% dependent on petroleum. Since the low-temperature heat supply could be taken over in principle, by any secondary energy source, a tremendous substitution potential exists here, which can be realized mainly by remote heat in connection with heat-power coupling, by gas, but also by new energy sources. In addition, the potential for conserving energy through thermal insulation, energy-saving construction, passive solar-energy use and better heating systems, is large.

The sphere of process heat, which makes up about 75% of the final energy consumption of the industrial sector, is irregularly distributed to the various temperature ranges, with particularly high demand for low (100 - 300 °C) and very high (1,200 - 1,500 °C) temperatures (fig.3). The supply to this sector is made up almost equally by the sources of coal, oil, gas and electricity. Potentials for energy savings and substitution of oil are not evident in this sector as they are in the household sector. Notable improvements can only be achieved through a differentiated analysis of individual production processes and by development of suitable methods.

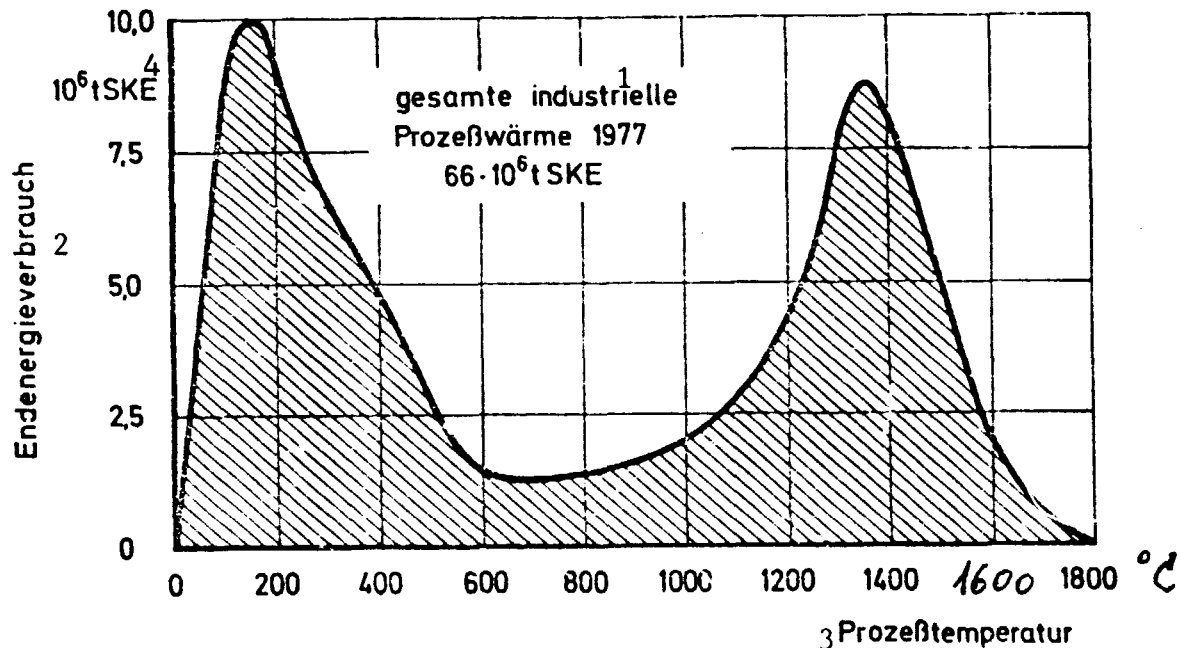


Fig. 3: Industrial Consumption of Process Heat as a Function of the Process Temperature (Source: Forschungsstelle fuer Energietechnik, Munich)

Key: 1-total industrial process heat for 1977 in hard-coal units
2-end-energy consumption 3-process temperature 4-million tons of hard-coal units.

The transportation sector continues to be dominated by petroleum. Due to the high percentage of individual transportation, improvements can be achieved mainly by energy-saving vehicles, whereas in all other sectors, the substitution potential is far greater and more promising.

The secondary energy carriers, electricity and remote heat, are least dependent on specific primary energy carriers. Electrical energy in the FRG is generated in small, often only technically specified portions, from petroleum (see fig. 4), so that the direct substitution potential is small. But indirectly, energy carriers which can substitute petroleum, can be replaced by electricity produced by nuclear energy. For example, natural gas and soft coal can be released in this manner and then replace oil directly (natural gas) or indirectly (soft coal by gasification).

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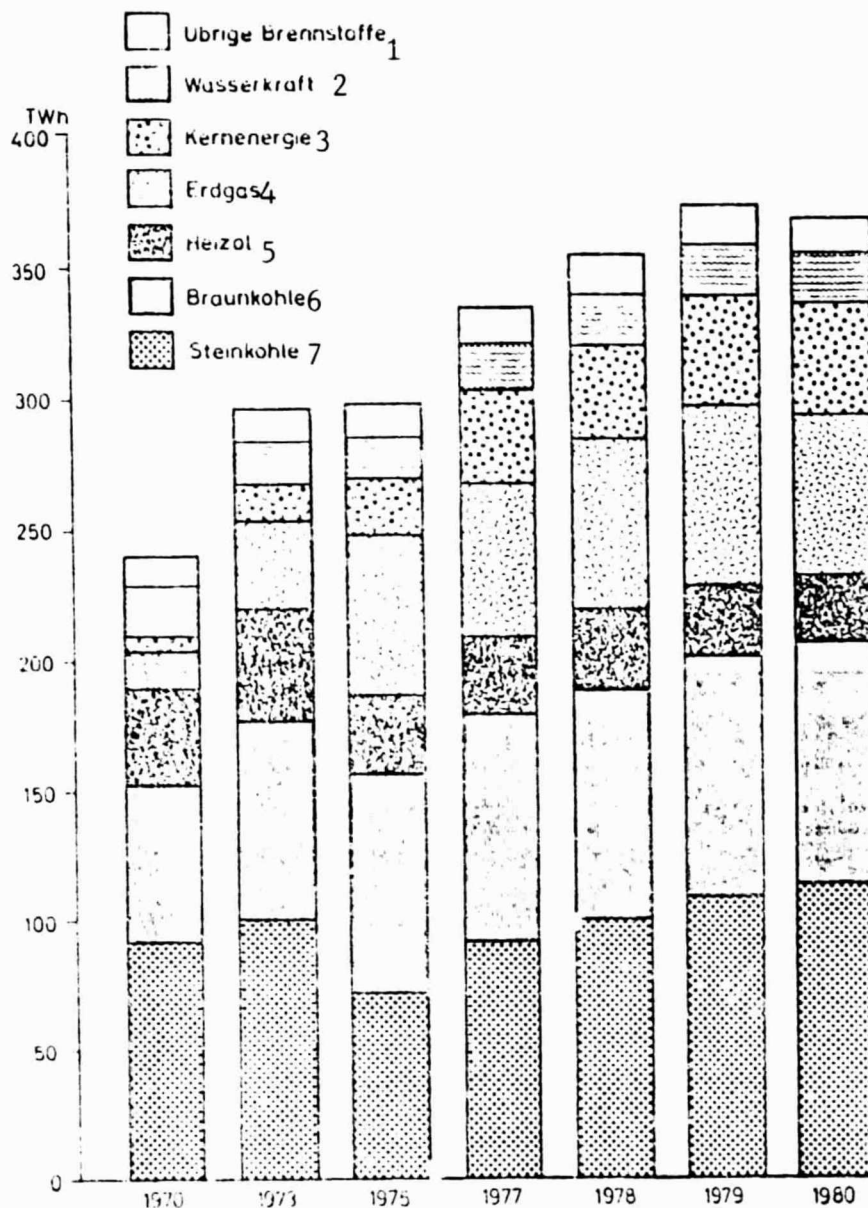


Fig. 4: Compilation of Primary Energy Useage to Generate Electricity in the FRG.

Key: 1-other fuels 2-hydropower 3-nuclear energy 4-natural gas
5-heating oil 6-soft coal 7-hard coal

The consumption of electrical energy has grown faster in the last decades, than the consumption of primary energy. The large electricity consumption in the FRG is primarily responsible for the losses in the conversion sector, which are about 14% of the total input primary energy. The good controllability of electricity in use compensates in many cases, the losses in the power-plant sector, which are about 60% in the heat powerplants, so that in many cases, especially in the industrial sector, a better primary energy utilization results than with other energy carriers. When using electricity

for low-temperature heating, this does not apply however; thus it should remain limited primarily to useage in periods of low demand.

In the interest of a rational energy useage, a remote-heat supply is becoming increasingly important, especially if it is available from industrial processes as useless heat which can be fed into the supply network. The small fraction of remote heat (see fig. 5 in the appendix) will continue to increase, in part at least through state funding of its expanded use.

The use of regenerative energy sources in the FRG is still in its infancy, in spite of considerable development efforts. For the German market, solar facilities for hot-water preparation were installed in 1981 which have ca. 200,000 m² of collector surface-area (corresponding to about 20,000 individual systems) and by the end of 1980, about 63,000 heat-pump systems had been installed to use ambient heat. The rapid tempo of market introduction has since slowed, due in part to the current situation on the petroleum market.

Overall, the development of energy consumption and of the energy supply structure shows that the adaptation of the German economy to the changed conditions of energy supply is progressing; but it continues to be a long-term problem whose solution can and must be promoted by research and technology.

1.2.2 Environmental Protection and Risk Reduction

Production, conversion, transport and utilization of energy are always connected with more or less severe pollution due to the release of waste heat, sulfur dioxide, carbon oxides, nitrogen oxides, hydrocarbons, aerosols, dusts or radioactive substances. In the evaluation of environmental effects, besides the operation of the plant, the pollution due to the necessary work of building the plant, must be taken into account, e.g. from materials' production for plant construction. In addition, the space requirement and consumption of other resources (e.g. water) must be noted. In order to avoid wrong estimations with regard to environmental effects of certain products and services, it is consequently necessary to take into account the cumulative energy consumption and the environmental factors connected with it. Regarding the overall subject of "Energy and Environment", the Council of Experts for Environmental Questions issued a report in 1981 and expressed research recommendations which were taken into account in the individual chapters.

Environmental effects due to the use of energy technologies must be considered separately. In individual cases, positive effects may result. But since the environmental effects are mostly unfavorable, it is one of the tasks of energy research to determine the environmental effects and to keep them as small as possible. This applies equally for all energy technologies, even though the need for this varies fr.m area to area. For coal technologies, reactor safety and nuclear fuel cycles, the environmental protection stands in the foreground of the development efforts.

Due to the environmental problems connected with the use of energy, a more rational energy use usually contributes to environmental protection. On the other hand, a series of pollution technologies, like many flue-gas scrubbers in coal power plants, require a greater energy use. Other goals, like e.g. humanizing certain jobs, are not always in agreement with the goals of saving energy.

Utilization of waste heat and the force-heat linkage for co-generation of electricity and heat in connection with a remote-heat supply are of special importance.

Suitable retention techniques can be developed for nearly every emission of pollutants. The development of economical methods is one of the main points of this energy research program.

The incorporation of environmental protection requirements into the planning and conception of new energy facilities is doubtless the most effective and lowest-cost method for reducing environmental pollution. An example of this is the fluidized-bed firing where sulfur is bound during the combustion process through additives to the coal in the combustion chamber, and thus only small amounts of sulfur dioxide will get into the flue gas.

The retrofitting of existing facilities where long-term investments are needed, and the improvement of established technologies with environmental protection equipment, can reduce the existing environmental pollution. It is not sufficient in this case, to merely await the development of new technologies and the construction of new plants. Rather, it is necessary to develop special devices to permit further utilization of the particular facilities and technologies. Viewed under this aspect, in the first energy research program the technologies for flue-gas scrubbing were pursued.

The neutralization of energy facilities is another important aspect of environmental protection and of safety. Radioactive wastes from the operation of nuclear power plants and from reprocessing facilities, including various slags, ash and deposited dusts from combustion processes, have to be conditioned and disposed of in an orderly manner. For the conditioning and final storage of radioactive wastes, there are already advanced technologies whose future, large-scale use will result in moderate costs for the commercial use of nuclear energy. The elimination of residues from coal combustion has been generally solved.

One special problem of coal useage is the slag heaps of mining; this can lead to river pollution which is difficult to reduce economically.

The entire primary energy is in the final analysis, fully converted into heat--with the exception of small quantities stored in chemical or physical form. In the FRG, this heat liberation is on average about 1% of the natural heat conversion. Regionally (in densely-settled areas and locally at power plant sites) the change in natural heat balance is greater. Certain industrial facilities are also special sources of waste heat. Besides unfavorable environ-

mental effects due to waste-heat emission to the atmosphere (e.g. shading and cloud formation due to wet-cooling towers), waste heat in a megalopolis can lead to improved ventilation and thus to a reduction of pollution from emissions of sulfur dioxide, nitrogen oxides, carbon monoxide and others.

Waste-heat emission to water, usually rivers, leads to additional evaporation and--unless counteracted--to a reduction in the oxygen concentration. Dry-cooling towers avoid this problem, but increase the energy consumption and thus the total output quantity of heat.

For some years it has been feared that increasing concentration of carbon dioxide (CO₂) in the atmosphere caused by the combustion of fossil fuels, will lead long-term to greater climatic changes. The political and economic consequences of such global climatic changes could be severe. The existing investigations and analyses to estimate this "greenhouse effect" do not yet permit any final determination. The CO₂-problem will therefore have to be further investigated internationally within the frame of climate research.

Another problem connected with the combustion of fossil fuels is the increasing acid content of precipitation, caused by pollutants like sulfur dioxide and nitrogen oxides liberated during the combustion. Once this acid and a number of other air pollutants are absorbed by water and soil, a whole chain of reactions sets in. The effects on the environment extend from the leaching of the soil to pollution by heavy metals.

Public debate on the risks of energy technologies has been concentrated primarily on nuclear energy. But it is becoming increasingly clear that all energy systems have environmental, safety and supply hazards, even though they differ in size and scope. Often, there is no reliable basis for estimating these hazards or of comparing the risks of different energy technologies. This applies in particular to the effect of pollutants normally liberated or those liberated in case of accident, including in particular possible teratogenic (gene damaging) and mutagenic effects of pollutants from coal burning. It is also necessary to use other technical and natural hazards as a scale for the assessment.

The Federal Minister for Research and Technology will refine methods for a better description of risks in the frame of a new research program on "Risk and Safety Research" and use them in real analyses of techniques for energy generation, transport, storage and conversion. These results can be the basis for specific technology developments to reduce particularly high risks. In addition, results of risk investigations should also be included in the complex interaction of economical, ecological and safety questions.

1.2.3 Social Consequences

Questions of energy policy are of great interest to the public. The primary desire here is for a sufficient, low-cost and reliable energy supply. This desire is linked with the expectation that the energy supply system be low-risk and environmentally compatible.

The estimation of possible effects of technologies has proved difficult, in addition to the fact that these effects are judged differently by individual population groups--sometimes they are judged oppositely. On the one hand, new energy technologies are viewed with increasing skepticism, on the other hand, many long-used techniques connected with risks and environmental and health hazards, are defended for economic or social reasons. Regarding new energy technologies, additional fears are expressed, like e.g. that their use could harm individual living conditions by changing requirements at the workplace, that political freedoms would be reduced and that new obligations would result. In this regard the important question arises regarding the retention and creation of jobs.

In this discussion about the effects of particular technologies and their acceptance, the type and structure of the decision-making process plays an important role. Previous discussion has made clear that energy-policy decisions on the use of certain techniques are made at many levels. For instance, citizens affect the structure and scope of energy consumption by choosing to conserve energy in space heating and transportation. At the state level, the Federal Government, states and communities bear equivalent responsibility for the future configuration of our energy supply.

The German parliament took a new track of parliamentary debate of the promises and risks of new technologies--in connection with the report on breeder reactor technology--in the 8th and 9th election term by creation of the Enquete Commissions on "Future Nuclear Energy Policy." The results of the first Enquete Commission have greatly affected the discussion of energy policy and technology policy.

This entire complex problem must continue to be investigated; it is composed of the interaction between the areas of constitutionality, law, economy and social-intellectual cultures. An attempt should be made to obtain a clear picture of the societal effects of new energy technologies through social-science investigations.

Technological questions which can have a significant influence on future living conditions receive great attention among the public. A prerequisite for an unprejudiced formation of opinion and a factual discussion is to have the greatest possible amount of information. The Federal Government sees its task as the obtainment of objective information on this subject.

Since 1975 the Government has conducted BMFT-sponsored information actions (discussions, seminars, presentation of information material) on nuclear energy in cooperation with the states. In recent years, the public discussion has expanded beyond the narrow framework of nuclear energy to the entire area of energy policy and technology (energy dialog). The Federal Government will continue this dialog with all interested groups and institutions under inclusion of environmental problems.

1.3 Balance-sheet of Previous Research Funding

At the time this program was conceived, State funding of energy research can look back to around 25 years of nuclear-energy development and almost ten years of funding for non-nuclear energy technology*.

During this time, considerable funds had been procured for promoting R&D in the individual spheres of energy research (see table 2 in the appendix). Even though not all projects attained the hoped-for success, overall considerable progress has been made.

Although the use of nuclear energy in recent years has advanced more slowly than originally expected, the technical success of the four Atomic programs cannot be overlooked. Through joint efforts of scientists, society and the state, the technological lag existing in 1956 was quickly overcome. With the operation of the 1,300 MW_e light-water reactor (LWR) at Biblis, the German nuclear industry demonstrated its arrival at the pinnacle of nuclear engineering. Not least, owing to the highly-developed reactor-safety engineering, German nuclear technology received a good international reputation; this was confirmed by a series of export contracts. In spite of the recent slow-down in domestic nuclear energy use, the German nuclear industry has retained its international position in the last few years as well.

In the area of the nuclear fuel-cycle, the development of the gas centrifuge was a tremendous technical success. Due to the peculiarities of the existing enrichment market prevailing in countries with military nuclear programs, the gas centrifuge still requires state support.

In the area of reprocessing of LWR-fuel elements, State funding has created the prerequisite for the construction of larger facilities.

The German Union for Reprocessing of Nuclear Fuels (DWK) founded by the Elektrizitätswirtschaft to perform the State-mandated reprocessing is increasingly taking over financial and technical responsibility. In important regards, it is still reliant on the cooperation of research centers and the use of test facilities like the WAK Karlsruhe, for additional know-how. As in the reactor development, so also after adoption and refinement of the reprocessing technology, before large-scale industrial useage, an important accompanying role still remains for state funding in the investigation of safety and environmental questions.

* Four Atomic programs (1956-1976), Framework program on Energy Research (1974-1977), Program on Energy Research and Technology (1977-1980)

In the conditioning and final storage of radioactive wastes, the FRG is far advanced due to timely, significant R&D funding. Above all, the years of operation of the ASSE test facility has set the world-pace for the final storage of low and medium-activity wastes. Technologies for conditioning and final storage of highly-radioactive wastes are far-advanced; their demonstration is pending.

In the development of the high-temperature reactor (HTR) the state R&D funding has meant that the reactor industry, according to its own information, can build HTR power plants of any power class up to 1,300 MW almost without any additional R&D effort. But industrial application of this line of reactors for power plants is not foreseeable. An important application of this reactor for additional state funding is the generation of high-temperature process heat, especially for coal gasification; but it has not yet reached technical maturity since the problems of materials and application engineering proved to be long-term difficulties in the course of the development. In addition, the economic conditions for coal gasification on the large scale needed for the use of offsite nuclear energy do not yet exist.

In the area of breeder reactors, the FRG is not a leading international member in regard to the operation of demonstration facilities, in spite of considerable financial efforts. Similar plants like the SNR 300 under construction in Kalkar, have been operating successfully, sometimes for many years, in France, Great Britain and the USSR with smaller ones in the USA, Japan and Karlsruhe (see table 4 in appendix). From the viewpoint of the long-term significance of this technology and the probable long time before market introduction in most other countries, this lag should not be over-estimated. For such complex technology, its incorporation into the technical-economic environment and its ability to obtain approval under differing international criteria, are decisive. By subjecting the SNR 300 to a normal licensing procedure, a time-consuming and expensive investment is made, but one which may be important for the future. Regarding the efforts of the State for a greater financial participation by the Electric utilities, in the case of the SNR 300 in Kalkar, a fundamental agreement has been reached with the utilities.

The very close partnership in breeder-reactor technology in Europe, especially with Belgium, the Netherlands and France and with the USA in selected areas, shows that the technical status is not fully described by the different construction status of the individual plants.

The fact that in the case of breeder reactor technology, a technology has been placed expressly under the domain of the Parliament for the first time in German history, has doubtless been stamped into the developments of past years. In other countries as well, especially in the USA at the end of the 1970s, breeder reactor development has been criticized.

In connection with the question of proliferation of nuclear weapons in connection with the increasing world-wide use of nuclear

technology, there was an international evaluation of the nuclear fuel cycle (INFCE, 1977-1980) with the participation of 66 countries and 5 international organizations. INFCE confirmed the importance of breeder technology for large industrial countries. This technology continues to be an important part of the energy research programs of all large, industrial countries (see tables 3, 4 and 5 in the appendix).

During the 1980s the expensive phase of erection of prototype and demonstration plants for some phases will come to an end; for the uranium enrichment project for example, and for the operation of the THTR 300 and SNR 300 power plants and for advanced reactor lines.

In other areas as well, like reactor safety research, the demand for state funding will probably decline as a result of previous advances. It must be taken into account that with increasing commercial use of light-water reactors, the manufacturer and operator will increase their efforts on safety refinements and on operating reliability.

The results of reactor-safety research have created a solid foundation for understanding the sequence and for evaluating the consequences of potential disruptions and accidents. The safety redundancy has been confirmed and more accurately defined. For instance, the results of reliability and rupture resistance of components of the cooling loop form the foundation for a new safety concept accepted by the Reactor Safety Commission, based on which the large pipe breaks assumed for the safety design of LWRs have been generally discounted.

Beyond the purely technical developments, the extensive, long-term research work on the environmental effects of nuclear energy, on radiation protection, emission retention, risk estimation and on general safety have reached a high level which can stand as a model for other technologies.

Controlled nuclear fusion has also been funded in the FRG for 25 years; world-wide it is still far from practical application. For a scientific understanding of plasma physics, in recent years definite progress has been made which brings a demonstration of the fundamental possibility within range. Important questions, e.g. the design of a fusion reactor, are still open. The investigation of the important technological problems decisive for practical use, including material questions, is still in the beginning stages. The attainable potential and the achieved advances do justify a continuation of the work at an appropriate level, especially in the frame of European cooperation with increasing concentration on the physical and technical key problems.

In the area of non-nuclear energy engineering, a successful balance-sheet under comparable circumstances is not presented, due to the shorter development time. After the initial, consciously very broadly-based funding, a greater concentration on promising technologies is now possible. Several technologies whose development was

funded in past programs, are at the market-introduction stage; this phase is sometimes simplified and accelerated by an active energy policy. Many developments are in actual testing and this hurdle has to be overcome before broad application is possible.

The funding of many non-nuclear energy technologies did not begin until after the first energy crisis in 1973, or at a time when the distance between the possible economic use-conditions and the established energy engineering seemed insurmountable. The dramatic energy price increases occurring in the meantime have shown that it was correct to judge the potential of new energy technologies not on the basis of the instantaneous competitive values. Thus, the market chances for a series of such technologies have grown considerably. On the other hand, it has turned out that for several non-nuclear technologies, the large gap in competitiveness cannot be reduced beyond a certain level through technical developments, even with further increasing energy prices.

The development of methods for coal enrichment not only enlivened the scientific-technical capacity in this area, but it also laid the foundation for the dedication of a coal enrichment program by the Federal Government in January 1980. In this framework, it was decided in Oct. 1981 to support the erection of demonstration plants for coal gasification and to fund preliminary work on building one or two demonstration plants for coal liquifaction. New technologies with additional, large development potential, will be used. The international technological advance guaranteed by this must be defended under consideration of the large efforts in other countries, especially in the USA and Japan, by continuing funding for refinement of the technology. Thus, the demonstration of this technology domestically is also useful to assure export possibilities, if broad application encounters domestic economic problems in the use of our own hard coal.

Important improvements in environmental protection of coal power plants were achieved in the term of the first energy research program; many of these techniques are now in use. The funding must be continued with a changed emphasis (e.g. dusts, heavy metals). The funding of the Coal-Mining-Technique has made significant contributions toward increasing the efficiency of German coal mining and toward improving underground working conditions.

In the area of rational energy use, important contributions have been worked out within the frame of the energy research program. Long before energy conservation became a concept of public discussion, developments had been initiated whose broad application is today promoted by the energy policy. In this regard we mention remote heat, whose significance gives rise to greater optimism in connection with existing heat sources like power plants and industrial facilities through demonstration projects and plan studies. This contributes to the increasing expansion of remote heat, which has received a high priority in all energy programs of the government. With the funding of gas and coal-fired block heating power plants and heat pumps, additional prerequisites were created for saving energy, especially oil. In other areas, like thermal insulation, heat

regeneration and environmental utilization by heat pumps, the funding of studies, research, development and demonstration projects has made important contributions toward readying technologies for rational energy use whose broad application has been accelerated in recent years, e.g. by the "4.35 billion DM program".

Many technologies for rational energy use and to use regenerative energy sources are still far from economical use, in spite of this funding. This also applies, at least in Central Europe, for many areas of decentralized solar energy use to generate heat, with the exception of hot-water preparation in summer and of swimming pool heating. Characteristic for these technologies is that persistent problems cannot always be solved by additional R&D effort alone. Rather, for such technologies, the integration into an existing system and structures are of decisive importance. Thus, demonstration projects have proven to be a particularly important funding instrument. In connection with technically successful demonstrations, specific funding can accelerate a broad application and maturation of economically promising techniques.

Previous works on the utilization of solar energy have led to a realistic estimation of the potentials and limits. In particular, the previous successes in the projects for direct solar-electric conversion give occasion for greater optimism. The attained progress in the production of low-cost solar-cells and the still discernable development potentials indicate a possibility for applications up to the medium power range (1 MW_e) and justify increased efforts in the future.

The potential of large, solar-thermal power plants, especially in sunny zones of the earth, and of wind power plants, which might also see duty in Germany to a certain extent, can only be estimated after operating results become available from the projects erected or begun in the first energy research program.

Regarding heat generation, the passive utilization of solar energy for applications in the FRG are assigned greater chances than the use of active components, like e.g. solar collectors.

The facility prerequisites for the use of high-energy wastes have been developed in certain areas, to the extent that an increased incorporation into the energy supply is economically possible even today.

The additionally very broad and intensive investigation of other technologies for rational energy use and for the use of regenerative energy sources, provided no reasons for the supposition (during the first energy research program) that important areas or technologies were overlooked or had not been examined. Even if economic feasibility seems impossible for many techniques after performance of R&D projects, nevertheless the resulting, clearer evaluation principles for the chances of these energy technologies are an important result of the funding. From the viewpoint of high political priority of actions for rational energy use and the use of regenerative energy sources, this work to open up possible and probable potentials must be continued.

Application-oriented research and development work is no guarantee of success, whether it be in technical or economic regard, or with respect to timing at which a new technology will be available. A stepwise procedure can reduce this risk. After conclusion of a development phase, and before beginning the next--usually more expensive--one, the previous success is evaluated and the subsequent chances of success estimated, while at the same time, the number of possible technical variants of a development phase is reduced to the most promising possibilities. Of course, the total risk can be reduced, but not eliminated entirely. For instance, a series of projects both in the nuclear and non-nuclear sphere have led to technically successful developments, without there being a direct, broad economical use, even though this was estimated differently at the beginning of the particular development work. This applies e.g. for nuclear ship-propulsion, whose technically very successful development had to be terminated due to lack of demand. Another case might be e.g. electricity generation via solar-thermal systems, which have in part been successfully demonstrated, and where surely a longer time would have to be bridged until they become economically useful. Every future, application-oriented R&D effort is unavoidably connected with this type of risk.

In each individual case, under consideration of all conditions and estimation of the future potentials, a decision has to be made about further proceedings. In individual cases for example, a detailed documentation of previous efforts and results can be a sufficient basis for a future revival of the corresponding developments. In other cases, appropriate capacities have to be reserved in research facilities or industry in the interest of an effective minimizing of supply risks.

This balance is supplemented by additional results of existing funding in the individual chapters. In addition, the results of R&D projects were published in detail in periodical, summary status reports and final reports on the particular projects.

1.4 Framework Conditions and Program Implementation

1.4.1 State--Societal Cooperation; Reasons for State Funding

In our market-oriented economy it is one of the tasks of businesses to develop new technologies and to introduce them to the marketplace and to bear the expenses necessary for this. Business performs primarily projects with foreseeable technical difficulties and economic success. The particular importance of the energy supply and of new energy technologies for the entire economy requires State participation in important cases.

In addition to general promotion, financial support of R&D projects by the State is an effective and necessary instrument. However, before State funding begins, a thorough check must be made of whether private economic forces alone are sufficient to set in motion the desired development and adaptation processes in time or with the necessary intensity.

It must also be taken into account that in suitable spheres, economically desirable developments can be promoted by establishing boundary conditions, e.g. by certain regulations on environmental protection. The instrument of financial aid however, is usually the more appropriate because of its flexibility and adaptability to the often differing conditions and requirements in practice.

Reasons for State funding can be when:

- Developments with a high scientific-technical and economic risk are under consideration, e.g. because the development times exceed the foreseeable times normally used by a firm for a product development and the financial expenditure is too large for the particular firm.
- Technologies are to be worked on under considerations of national economy, where the development in the given market situation will be insufficiently performed or not at all.
- Important considerations of the environment, of population and job protection are taken into account too little in technical developments.

In addition, State funding of fundamental research is needed wherever information has to be gained about effects of energy techniques (reactor safety, final storage etc.), e.g. for the issuance of laws and regulations. These research efforts and application-oriented R&D projects are generally performed in State funded research facilities, e.g. large research centers.

For R&D projects of business, the firms must bear an appropriate portion of the costs since they will later be the users or producers of the developed technologies or research results. Thus, R&D projects of business are generally supported only up to 50%. In cases of particular public interest or especially large risks for the particular firm, the funding percentage can be higher, but then lower once the development approaches the marketing stage. For long-term and high-risk developments however, the financial responsibility will not remain permanently with the state, since otherwise the danger of wrong developments and later failure in the marketplace will become too great, in spite of considerable public expenditures.

In the promotion of market introduction of new energy technologies after their successful demonstration, particularly strict scales of measurement must be set up.

The fundamental R&D work to open up nuclear and non-nuclear energy technologies has progressed relatively far in many cases. Regarding the steps of research to the development and innovation, in the future the expensive phases of construction and testing of demonstration facilities and their broad application will become more important. Even more than before the firms will be supported in the future.

Industry initially has a direct interest in the development of new technologies, especially industries producing the energy systems. Only through technological refinement and cooperation in new key technologies can they maintain their efficiency on the world market.

The energy supply companies as well, have an interest in modern, high-performance technologies. In particular it is important for them that the development be structured so that the new technology is available in a suitable form and at the proper time. Therefore, in the future a greater participation and responsibility of the utilities is desirable in energy research. From this results a corresponding cost accrual to the energy consumer for research expenses.

Due to the large number of technologies of importance for the generation of electricity in the energy research program, this requirement is directed mainly to the electricity utilities (EVU). With this background and due to the positive estimation of breeder technology by the utilities, the desire of the Federal Government for a greater financial participation of the utilities in the prototype breeder power plant SNR 300 in Kalkar is understandable. This requirement was supported by all factions of the German Parliament. With the support of the particular state governments, the Federal government obtained a fundamental agreement in discussions with the electric utilities. Accordingly, in future more than 25% of the costs of the facility will be borne by the utilities (originally this amounted to about 8%). The Federal government is pleased that the Bundesverband der Deutschen Industrie (BDI) has declared that the advanced reactors play a prominent role in our country's participation in world-wide technological developments in this area. It was also expressed that this greater financial participation of the utilities will be reflected in the price of electricity to the extent that increased costs cannot be absorbed internally by the affected utilities, and it must be assured that the industrial users will not be penalized more than the household users.

The Federal Government is of the opinion that overall, the additional costs connected with this are small and manageable under consideration that long-term investments are made possible to reduce the energy-supply risks.

Regardless of the SNR-300 financing, the Union of German Electricity Works (VDEW) is endeavoring to establish a voluntary, joint research fund by the electric utilities. The Federal government is pleased with and supports this initiative in the interest of a greater company responsibility and participation in technological development.

An international comparison shows that the electric utilities in other countries often provide considerable funds for the development of future, needed technologies. For example, a large number of electricity companies in the USA provide an annual total of \$260 million on a voluntary basis for the financing of the Electric Power Research Institute (EPRI). The Japanese utilities finance annual R&D work on electricity generation and distribution, on a voluntary and prescribed basis, in the amount of ca. 1.5 billion DM. In other

countries as well, where privately organized electricity utilities exist, e.g. Spain, the electricity utilities (EVU) provide an important contribution toward the financing of energy research. In this regard it must be pointed out that the State EVU e.g. in France, Great Britain, Italy often provide considerable sums for development and market introduction of new technologies.

The requirement for a greater financial participation in R&D is limited not only to the electricity companies. Other branches of the energy industry are urged in future to make intensified efforts. The future of new, large projects and areas of the energy research program will depend on the readiness for a greater involvement by these firms.

In the interest of competitiveness of our domestic economy in the international market, the FRG must have cooperation of the energy industry, the system-manufacturing industry and the State. The government will continue to work toward an improvement and intensification of this cooperation.

1.4.2 Priorities

Based on the goals and objectives of the energy research program explained in the introduction, the other priorities evolved through continuing dialog between business, science, government and parliament. In recent years, the German Parliament has been increasingly concerned with questions of energy research policy (two large and 20 small hearings, 16 motions, 16 decrees and 152 oral and written questions during the 8th legislative period). When establishing this program, in particular the report of the Enquete Commission on "Future Nuclear Energy Policy" of the 8th German Parliament and the results of his council were noted in the parliament. The R&D work prescribed in the program should permit an expansion of the frame of action of energy policy as defined in the Enquete report.

When making decisions about individual technologies, their potential contribution to attaining the program goals must be taken into account. Besides the theoretical potential of a technology, the probability of its economical utilization must be taken into account. Furthermore, aspects of environmental compatibility, reduction of reliance on foreign imports, reducing supply risks and relieving the outflow of capital as well as possible effects of energy technologies on our political and social system have to be taken into account. Besides these aspects (the national energy supply stands in the foreground), the funding of energy technology e.g. in developing countries, can be important, even if these technologies have little or no importance for our energy supply. New energy techniques can thus improve the domestic and world-wide supply situation, prevent international distribution fights for dwindling resources and relieve international tensions.

Aspects of industrial policy play an important role in the funding in order to maintain the international cooperation of German manufacturers.

Basically, technologies should be funded earlier, the more they contribute to fulfilling the named conditions.

Advisors named by the government play an important role; they formulate their recommendations under consideration of experiences from completed and on-going projects.

To evaluate many of these questions, inter-disciplinary studies, system analyses, model calculations and social-science research work is needed.

When setting and changing priorities and procuring appropriate funds, a series of special boundary conditions must be noted in the research, development and demonstration. The most important of these are discussed briefly below.

The successful implementation of R&D projects usually takes several years. This is particularly true for the implementation of large projects. Thus, continuity of research funding is a minimum prerequisite for success. The requirement for continuity results from the fact that the effective research facilities cannot be quickly built up with personnel or expanded; severe reductions can cause social problems and permanent loss of qualified personnel.

In addition, different energy technologies can pose completely different R&D problems. Besides the probable contribution to the goals of the program and the needed development times until market introduction, it must be taken into consideration that the solution to these problems often requires a quite different, specific use of funds. Extreme examples for this are the development of a solar collector and the investigation of controlled nuclear fusion. Other differences in the needed funds useage can arise from a different development status of the technologies from the fundamental research in laboratory and pilot plants down to expensive demonstration facilities to market introduction. The ratio of funds spent for various research areas thus cannot be taken as a direct measure for the priority attached to a technology by the Federal Government, due to the different properties of various technologies.

One special problem is that of market introduction. In "central" large-scale technologies it is usually sufficient to successfully demonstrate a plant to verify the utility of the technical solution. Through the information flow between operators and manufacturers, the construction and operation of other plants is possible, provided economical operation is assured. For decentrally used technologies, even several demonstration plants are often not sufficient. The growth of a new technology into the existing infrastructure must also be promoted in the future since often, the actual maturation process of a technology can only proceed with this system introduction. The funding of this process is no longer a component of this research project, but does belong in a broadly understood innovation promotion within the frame of general energy-policy actions, e.g. the 4.35 billion DM program (overview of this is in table 2 of the appendix).

1.4.3 Funding and Implementation of the Programs

This program comprises the actions of the Federal Government for R&D in the energy sphere. The Federal Minister for Research and Technology is the managing officer for the program and with a few exceptions, is responsible for its funding. The initial innovation in hard-coal mining and in the building of commercial facilities for coal gasification are being funded by the Federal Ministry for Economics (BMWi). The Federal Minister of the Interior is responsible for radiation-protection research and for reactor-safety research directly relevant for the nuclear licensing process, and for environmental research within the frame of formulation of environmental protection laws. The Federal Ministry for Regional Planning, Construction and City Planning (BMBau) is responsible for construction-related work. In addition, funding of projects for energy generation and conservation in agriculture, including the use of raw materials is by the Federal Ministry for Nutrition, Agriculture and Forestry (BML). The development of energy technologies for developing countries is performed jointly with the Federal Ministry for Economic Cooperation (BMZ).

The funds are contained in the budgets of the particular Federal departments and are enumerated in the tables of the appendix. By far the largest part of the funds for this program comes from the budget of the Federal Ministry for Research and Technology. The expenditures of the BML, BMV, BMBau and BMZ relevant to energy research are an integral component of the departments' expenditures and thus cannot be enumerated separately. The execution of the program proceeds in cooperation between the affected Federal Departments.

In many areas there is cooperation with State governments. The cooperation with the "Coal states" of North-Rhine Westfalia and Saarland, and that between the states having large research centers is quite prominent; the states provide 10% of the financing of the large research centers.

The program includes the planned work in the frame of project-related funding for the economy and for scientific facilities. Also, there is funding for energy related research by large research facilities.

The use of funds for the energy research program is governed by the Federal budget and finance planning. The amount of funds is determined by the approval of the annual budget by parliament. Changes in the budget or financial planning cause changes in program financing. The tables in the appendix show the funding for the problem-areas of the program.

The emphasis on funding of energy technologies for a series of technological developments can only be taken up by large firms with appropriately large abilities for risk compensation and which have extensive R&D capacities.* Examples are nuclear engineering and projects of coal gasification and liquifaction. A certain unequal

*T.N.: Improper sentence in the original.

distribution of funds to large and small firms is connected with this. However, it should be taken into consideration that for large projects in particular, many jobs can be sent out to subcontractors and this will reduce the inequality. In addition, the Federal government endeavors to increase funding of small and medium-size firms within the frame of energy R&D projects. An improved inclusion of small and medium-sized firms in those sub-programs of the BMFT is desired, especially where the goals and needed technology provide pertinent possibilities for these companies. This includes especially the areas of: Rational and conservative energy use, R&D in the area of alternative energy technologies. .

Funds from this program which are to be used for project-related promotion of energy research, can be requested by any firm, university or other scientific or technical institution. The publication of this energy research program containing program fundamentals should serve as a promotion. The details of application, the sequence of the project and the funding conditions are described in the "Funding Handbook" of the BMFT.

For handling the application, their examination from a technical and economic viewpoint, for estimation of success, for the administrative evolution of a project and its management and control, the Federal government makes use in many cases, of consultations with project consultants. However, the funding decision is made by the particular Federal department. A list of project executors is found in the appendix; the largest one is the "Energy Research Project Management (PLE)" at the nuclear research center, Jülich, which manages the entire area of non-nuclear energy research.

Close contact is maintained to the performing agencies via the project executors. In particular for smaller and medium-sized firms, the project executors provide assistance in formulating the applications and in the definition or limitation of the research projects, and in administrative matters.

If necessary, the Federal government and project executors use external consultants in the evaluation of research projects. The advisory councils of the Federal Ministry for Research and Technology are announced annually in an advisory plan.

In order to assure that public funds are used effectively to support R&D, a success-control is performed at several levels. At the project level the particular project executor or specially delegated project manager monitors project progress. If necessary, presentations of interim results are requested. In many cases--especially in projects performed with international cooperation--there are regular reports to the guidance committees. During these investigations during the course of a project, decisions are also made as necessary, on implementation and goals, which can even result in termination of a project.

After conclusion of the project, the results are evaluated. The use of funds is verified by compilation of an accounting ledger.

By means of publications of various type, a broad dissemination of the research results is assured.

At the program level there is a "success" check by means of discussions, regular conferences of experts at status seminars and in circular letters. On-going international information exchange occurring bilaterally and in multilateral committees (EG, IEA) contributes to the "success" check.

1.5 Research Facilities

A considerable part of the actions of the program is performed in large research facilities, especially in the centers at Garching (IPP), Geesthacht (GKSS), Jülich (KFA), Karlsruhe (KfK) and Neuherberg (GSF) (See table 1, appendix).

In addition, the universities will continue to participate in this program, either in cooperation with other research facilities and industry, or independently. Especially where fundamentals have to be worked out, or where it is important to estimate the consequences of technologies, universities can provide an original contribution to energy research. Several energy research projects are also financed by the German Research Union for special research projects.

With the exception of the GSF and IPP, the above centers have been in operation for over 25 years. They were founded in 1956 at the beginning of funding for nuclear research and technology in the FRG, in order to make a contribution toward closing the technological gap existing at that time. They had clear models, like the building and operation of the first German reactors, the development of nuclear ship propulsion or the investigation of plasma physics as the foundation for the use of controlled nuclear fusion. In addition however, other subjects were included in the programs at an early date, like fundamental research and various types of applied research. Thus, the nature of the centers has changed over the years: The KFA Jülich for example, today performs a large amount of pure, fundamental research, conducted primarily in cooperation with the universities of North-Rhine Westfalia, in addition to its application-related energy-research projects, whereas the KfK Karlsruhe is concerned primarily with nuclear R&D projects with a much smaller portion of fundamental research.

The centers have found a unique role between fundamental research and industrial development over the course of 25 years of solving R&D problems in the public interest.

Today, GKSS, GSF, IPP, KFA and KfK employ 9,500 workers, including employees in areas not relevant for energy research, and have a budget of over 1 billion DM per year. The level of funds necessitates a regular discussion and examination of the centers' programs. The remaining, even growing problems of nuclear fuel cycle, reactor safety research and advanced reactors continue to require the contributions of the research centers.

The research centers make a contribution to the continuity of refinements of complex technologies which would hardly be possible by industry alone, in the frequently long times until broad utilization. In addition, it turns out that those technologies connected with questions of environment, safety and risk, lend themselves particularly well to close cooperation between industry and research centers. They are thus an important partner for the State in the preparation of research-policy decisions based on critical and independent observation of scientific-technical developments.

So the research centers will continue to be an important partner in research policy. But it is important that they continue to adapt to the growing demands and changes brought about by the pace of development.

The work of the IPP in Garching by Munich is directed entirely toward nuclear fusion research, with special emphasis on plasma physics. The work is concentrated primarily on two large pieces of equipment: The Tokamak ASDEX and the Stellarator Wendelstein VII-A. It is planned to expand these units in coming years. In addition, in future an increased cooperation with the large European experiment JET in Culham and preparatory considerations for the international project NET/INTOR will move into the foreground.

The GKSS research center in Geesthacht was originally founded to develop the nuclear ship drive. This goal has indeed been attained with the concept approval for a nuclear-powered container ship with a power output of 80,000 WPS (NCS 80) and the successful operation of the OTTO HAHN, but industrial useage of this technology is not foreseeable, primarily for economic reasons. The center thus has reoriented broad areas of its activities. New goals are problems from the area of LWR-safety research, the investigation of complex, interdisciplinary environmental problems of lake and coastal waters and underwater engineering with large underwater simulation facilities GUSI, which will go into operation at the end of 1982.

Development of the high-temperature reactor was the main emphasis of work at the KFA Jülich for many years. The fundamental research on the reactor and on the fuel cycle has now been mostly concluded. Thus, the work in coming years will be reoriented and will concentrate on areas of application for high-temperature heat. In order to do this, the KFA will be concerned with the development of process techniques and high-temperature materials. Potentials for a later test of these developments under real conditions will be checked. High-temperature process heat would over the long term, be used not only in coal enhancement, but also for improving lower-quality fossil fuels. The technological questions connected with this are being examined by the KFA in a project "Future Fossil Fuels". The activities on the HTR-fuel cycle will be concluded with the work on the JUPITER-system and on direct disposal of the HTR-pellets. In addition to these energy projects, the KFA will in future be concerned with questions of energy and environment. Additional projects are the TEXTOR fusion program, material properties and research, and nuclear fundamental research. Furthermore, the possibility of erection of a spallation source at the KFA Jülich will be examined.

The research emphasis of the KfK Karlsruhe in the energy area will be, during the program term of the breeder, the LWR-reprocessing, the LWR-safety research, the separating-jet method of uranium enrichment, deep-disposal of radioactive wastes, and fusion research. Work on the breeder will focus in coming years on questions of licensing of large breeder-reactor cores. In addition, the adaptation of technology of reprocessing to breeder fuel elements will be handled increasingly. The work on the LWR-reprocessing will be directed primarily toward key questions of safety of large reprocessing facilities and on the whole, will pass more and more to industry. The KfK is a research center oriented primarily toward large-scale engineering and will assume longer-term tasks of development of fusion reactor technology. Besides its previous work in the energy area, subjects from the area of energy and environment will be explored, perhaps within the framework of climatic research. The other work of the center should be reoriented over the medium-term to environmental questions or to new problems of fundamental research.

The work of the GSF in the energy area includes environmental and radiation-protection problems in connection with the generation and spread of radioactive wastes. This subject requires a high level of interdisciplinary work. For the investigation of final disposal of radioactive substances, the ASSE salt mine is available. Besides these energy-oriented efforts, other problems handled by the GSF are the biological-medical action of environmental chemicals and radiation, methods of health restoration and material balances in the ecosphere.

Besides the five centers dealing mainly with energy research, the Hahn-Meitner Institute (HMI) is cooperating on special questions of nuclear decontamination. The German Research and Test Center for Air and Space Travel (DFVLR) is also active in some areas of non-nuclear energy research, especially the Stuttgart research center dealing with solar energy.

Overall, the large research facilities have attained a size which is appropriate to their tasks. The inclusion of new subjects is thus in most cases linked to the conclusion of previous activities. This requires a high level of flexibility for the employees. The restructurings in the past have shown that this flexibility does exist. But this is not least a success for the participation of employees in the decisions which are important for the future of the particular centers. These cooperative structures will be retained during the program term.

Increased attention will be dedicated in coming years to the matter of technology transfer. But work will be directed primarily to those areas where the centers have particular competence. Promising indications on this topic have already been found in past years.

1.6 International Cooperation

International cooperation is of particular importance in the area of energy research and technology policy, for several reasons:

- Similar problems in energy supply of nearly all countries require similar efforts for their solution. Cooperation and work allocation permit a more rational utilization of available information, capacities and finances. They permit the individual countries to withdraw from active working on a particular problem-area and to rely on the information flow from participating countries or international organizations, in order if necessary, to recommence activities.
- Environmental and safety problems of energy technology, especially pollution of atmosphere and waters and the safety of nuclear facilities require international solutions, especially in densely populated Central Europe.
- Timely cooperation in R&D is an important prerequisite for future open markets and for the development of uniform standards.
- Developing countries face particularly severe problems of energy supply due to their economic lag coupled with a growing population and because of the repressive reliance of many of them on imported oil.

For these reasons, the FRG is participating in many programs and projects of international cooperation in energy research and engineering, both on the basis of bilateral agreements with other countries, and also within the frame of international organizations or multilateral agreements.

The individual actions of international cooperation are described in the pertinent chapters in connection with domestic activities. An overview of the network of international agreements and programs with FRG participation is presented below.

1.6.1 European Community

From its very beginning, the community has promoted R&D for peaceful use of nuclear energy. Since 1974 these activities have been extended to broad areas of non-nuclear energy.

Their own research facilities employing over 2,500 workers at the centers in Ispra (Italy) and Petten (Netherlands), at the European Institute for Transuranium Elements in Karlsruhe and at the Central Office for Nuclear Measurements in Geel (Belgium) are available, as well as extensive means for issuance of research contracts. The total annual expenditures are over half a billion DM; of the amount specified for research contracts, around 30% is awarded to German institutes and firms.

The European Community (EG) research policy has achieved the highest level of integration for controlled nuclear fusion; EURATOM is coordinating all important projects in the EG and in Sweden and Switzerland and the large JET experiment is being performed jointly by all parties (see sec. 5). Other projects concern reactor safety, radiation protection, nuclear material safeguarding, plutonium and actinide research, standardization, solar energy, geothermal and rational energy use and storage.

1.6.2 International Energy Agency (IEA) of the OECD

Besides their tasks of assurance of the oil supply and in other areas of energy policy, the IEA also promotes cooperation of its member countries in research and engineering. The individual projects and programs pertain primarily to non-nuclear energy and are being performed on the basis of agreements of interested member nations--usually under management of one national agency. These projects extend from energy-strategy studies to pilot or demonstration plants, like the Major comparison between various solar power plant designs in Almeria (Spain)--see sec. 4.1.2. The advantage of the cooperation within the IEA-framework--in which numerous German firms and institutes (sometimes managing) participate--is due to the fact that each country is free to determine its participation in individual projects and their scope, within the frame of the particular, existing agreements, while still participating in major discoveries of all projects.

For example, the IEA membership of the FRG offers the potential for keeping updated about developments in areas of energy research in which Germany itself has no notable activities, like e.g. wave or sea-temperature gradient energy.

1.6.3. Nuclear Energy Agency (NEA) of the OECD

For the FRG, participation in the work of the NEA is important primarily for reactor safety research and questions of the nuclear fuel cycle; it permits access to a broad international information and experience-exchange and to large test facilities, like the Eurochemic reprocessing facility (now used for practical testing of waste treatment methods) and the Halden experimental reactor.

1.6.4 International Atomic Energy Organization (IAEO)

Even though the emphasis of the IAEO lies in the application of safety measures for the peaceful use of nuclear energy and in practical aid for developing countries, there are also possibilities for taking part in world-wide information exchange in many areas important for nuclear research and technology, especially reactor safety, refinement of techniques for safeguarding nuclear material and the use of nuclear energy under the special conditions of developing countries.

1.6.5 Other Multilateral Organizations

Special subjects relevant for energy research and engineering are being investigated in numerous organizations (world wide by VN, UNEP and others; regionally by the ECE)--especially since the first oil crisis of 1973--with various amounts of German participation, where the main advantage lies in the illumination of special problems and developments abroad and their potential effects on the FRG, and in the expansion of the volume of information.

1.6.6 Bilateral Cooperation

Excepting an intensive international exchange of information, experiences and opinions between scientists and industrial facilities--which often cannot be affected by the State--energy research and engineering development in the FRG provides a varied picture of work allocation and cooperation with other countries in individual projects or in exclusive programs.

Cooperation with the industrial countries of West Europe and North America has proven to be particularly valuable because they are following in important areas, the same development directions as the FRG. This offers us the chance to distribute the financial and personnel burdens of R&D, especially in large projects, to two or more countries and to obtain access to developments which may be ahead of comparable German work. At the same time, such cooperative projects simplify timely establishment of industrial cooperation and thus of market introduction of German technology and products in partner countries, and also into third countries. Prime examples of this type are mainly in the area of nuclear engineering, e.g. the broad cooperation with France on breeder development (including also Belgium, the Netherlands and Italy), and also with Japan and the USA in some regards, and the joint development and use of the gas-centrifuging method for uranium enrichment together with Great Britain and the Netherlands.

An example of how international cooperation simplifies activities in very advanced, but high-risk developments through work division, is the German-Belgian project on underground gasification of coal deposits in which France has recently shown an interest.

When cooperating with developing countries, the motive of helping them gain independence from the oil-price explosion, stands in the foreground. Cooperation in R&D on new, especially renewable energy sources should enable them to form their own judgements on the chances and problems of new technological solutions from the very beginning, to then master the technology and later to apply it in practice, without constantly having to rely on foreign assistance. But a prerequisite for this is a certain level of scientific-technical infrastructure in the country itself. On the other hand, cooperation with developing countries permits participating German institutes and firms to test and improve their own ideas and developments, e.g. on solar or wind-energy utilization, under other, more favorable conditions, and thus to prepare export markets for their products or even to improve potential applications in the FRG itself.

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Among the numerous projects undertaken at various scientific-technical levels with cooperating developing countries are:

- Comparison test with 120 hot-water heaters of various design in Egypt
- 100 kW solar power plant and a 3,000 m³/day desalination plant in Kuwait
- 20 kW wind energy system in Argentina
- A system for gasification of biomass (agricultural wastes) in Indonesia
- Integrated use of regenerative energy sources for powering rural areas (so-called "Solar villages") in the PRC, Greece, Mexico.

In addition, specific funding by the Federal Ministry for Scientific Cooperation (BMZ) supports the developing countries in their efforts for local production and expansion of energy technologies. The activities to develop and use renewable energy sources are summarized in the "Special energy Program (SEP)" of the BMZ.

2. New Technologies For Rational Use and Generation of Energy

From the viewpoint of the considerable increase in energy imports, a more rational use of the available energy, especially of oil, has become increasingly important in recent years. This is clearly reflected in the increased efforts in R&D in the area of conservative energy useage. The first Enquete Commission of the Bundestag on "Future Nuclear Energy Policy" emphatically pointed out the significance of rational energy useage and provided corresponding recommendations. The recommendations in the decree of the German Parliament on the first Commission of Dec. 1981 (Bundestags Drucksache 9/1147) have been taken into account.

For processing and conversion of primary energy into a form useful for the consumer, one must expend a considerable portion of the input primary energy. In addition, the use of end-energy in the various consumer sectors is connected with losses which are estimated to be about 45% for industry, about 55% for households and small consumers and about 80% for transportation. Overall, today about 2/3 of the input primary energy cannot be used. For technical-physical reasons, these losses however, may not be equated with potential savings.

The reduction of losses in conversion and use by means of new techniques is one of the most important problems of energy research. But the potential savings in certain conversion or use-technologies cannot be considered in isolation, rather in each individual case, the entire conversion chain must be considered--from the primary energy down to the used portion of end-energy. For example, in the generation of electricity with thermal power plants, the losses of about 60% are relatively high, but when using the electricity, it has the smallest losses. In connection with the controllability of electricity, it can lead to a high efficiency of input primary energy in numerous processes. An example of this is the large energy savings achieved through the electrification of the German railroad.

Due to the environmental problems connected with the use of energy, a more rational energy use usually also contributes to environmental protection. On the other hand, a series of environmental protection techniques, like e.g. flue-gas desulfurization in coal power plants, requires a greater use of energy. Other goals, like humanizing the workplace (e.g. shift-labor) are not always in agreement with the goals of saving energy. In general it must be noted that the goal of energy policy, the "Way away from oil", must in many cases result in the abandonment of many techniques which would permit overall lower energy losses, but require a higher consumption of oil.

Due to the complexity of relationships, more rational use of energy is not only a technical problem and a question of economy, but is often a problem of information and careful examination of each individual case.

Due to the rising energy price in recent years, the significance of technologies for more rational energy use, including regenerative energy sources, has grown. In order to keep up with this pace, the various technologies have to be further refined toward the goal of increased efficiency, reliability, service-life and economy; this must go hand in hand with a practical and specific flow of information.

Due to the structural aspect of rational energy use, cooperation of the local entities with the supply source is of great importance in city and housing planning.

In the development of technical measures--especially for large consumers--the following procedure is recommended:

- the demand for useful energy is to be reduced as much as economically feasible
- the unavoidable exhaust heat should be used for internal heating needs
- the remaining demand must be covered by the smallest possible use of primary energy, especially oil.

Naturally, these general rules do not replace a careful weighing of costs and benefits. This applies especially for large investments, like e.g. when building a remote-heat network.

To generate low-temperature heat (space heat and process heat up to a temperature of about 200 °C), at present in the FRG about 50% of the input energy is consumed. It is thus particularly important to reduce the energy consumption for meeting low-temperature heating needs. In spite of the decline in oil consumption in recent years, there are still large conservation potentials right in this area, through better thermal insulation, expansion of waste-heat utilization, increased use of heat pumps and improved application of measuring and control equipment.

There is a series of R&D projects on the rational use of energy which should make energy use more efficient, e.g. by improving heat transfer in heat exchangers, improved thermal insulation, reduction of costs for transport and storage of heat, suitable selection of

cooling and working fluids and by reducing losses through improved controls. Frequently, long-term testing is needed, since the economy depends greatly on the service-life of energy-saving systems. An important point in this regard is the selection of materials and materials research.

Besides these extensive R&D projects, part of which is still fundamental research, applied projects predominate here, where practical problems are solved and the economy or sturdiness of energy saving systems is improved.

The availability of matured components does not yet guarantee the maturation of energy systems composed of them. The interaction of components in the entire system and the testing of this system under various conditions is thus among the most important R&D tasks in this area.

Among the research problems are also extensive investigations on a regional and local energy supply concept. Such concepts can significantly improve the effectiveness of individual measures for rational supply and use of energy. The Federal government has already pointed out this fact in the Third Continuation of the Energy Program and in the 2nd Immission Prevention Report. Energy supply concepts contribute toward a long-term, meaningful structure of energy used for heating purposes, especially regarding remote heat from power-heat coupling or industrial waste heat, gas and electricity. This can bring the housing structure into harmony with the goals of city planning, urban renewal and environmental protection. The Federal government will continue to work for the broad acceptance of supply concepts; it is funding utility companies and communities in efforts in this regard. Also, technical studies and planning studies and investigations of urban planning are being prepared in a research program "Local and Regional Energy Supply Concepts"; this is intended to aid utilities, cities and communities in developing such concepts. In a coordinating committee "Local and Regional Energy Supply Concepts" accompanying the work, the Federal and state governments, utilities and communities and local entities are all represented.

2.1 Application Technology for the End-user

In order to determine those technologies which have the greatest conservation potentials, systematic investigations were already performed in the first energy research program. The goal of these investigations--which were continued as necessary--is to find the amount of secondary energy needed to attain the required energy savings.

The greatest short-term and medium-term recoverable savings potential was determined to lie in the sector of household and small consumers, to which therefore most of the research work is now dedicated.

In the past, conservation measures in industry have led to increasing reductions in the specific energy useage. This was especially true when the energy consumption was a particularly important cost factor. In order to accelerate this trend, the EMFT has funded appropriate developments in industry in past years, especially when considerable risks were involved. Promising progress was achieved in the ceramic, iron smelting and cement industries. In addition, developments aimed at internal or external use of waste heat have been promoted. A large part of these projects has not been concluded and will continue to receive funding in coming years. During this program shall be checked whether technology areas can be delineated in which an indirect-specific R&D-funding can be used in a promising manner. In this manner, small and medium-size firms will be supported in particular.

In the transportation sector, the primary conservation potentials are linked with structural changes which cannot be separated from fundamental refinements in transportation technology and are thus a constituent of the corresponding research programs. The research goals are thus presented here only as information.

2.1.1 Household and Small Consumers

In household and small consumer sector, energy is used predominately for heating buildings and hot water. The fraction of oil and gas is about 70%. According to available investigation results, the energy needed for this can be significantly reduced through construction and system-modification measures which are economical even today.

Energy-Saving Building Design

Previous investigations and projects have given the following rules for continuing research projects:

- In the passive utilization of solar energy there continues to be a knowledge deficite, especially with regard to quantitative evaluation.
- For projects aimed at improving thermal insulation, the causes of the increasing losses are to be investigated in connection with increased insulation of the outside surfaces and reduction of ventilation losses.
- For subsequent improvement of thermal insulation of existing buildings, design changes and physiologically safe, rational and low-cost solutions must be found.
- A generally recognized methodology for energy evaluation of existing building materials and potential modernization actions are needed by the design engineer to compute the energy needs of new construction.
- Investigations on the physiologically necessary ventilation and on technical potentials for controlled ventilation and heat regeneration must be expanded.

- Investigations of specific building-types with particularly high energy needs, especially of public buildings, like e.g. hospitals, are useful.

Heating Systems

Electric heat pumps have been developed. By the end of 1980 ca. 40,000 heat-pump systems had been installed in heating systems in the FRG. A more extensive market introduction is countered mainly by the relatively high costs and difficulties which led to a considerable reduction in sales in 1981.

Larger, gas-fired heat pumps in the 50 kW range are also currently available on the market and are used primarily in larger building complexes. In the FRG at present there are ca. 300 gas-heat pumps in operation.

Smaller gas-heat pumps for one- and two-family houses are under development. In addition, the following developments are promising:

- Small diesel heat pumps
- absorption heat pumps and investigations on corresponding material cycle properties
- Investigations of the heat absorption from various heat sources
- Component development to improve the efficiency
- Heat-pump development for special purposes (industry, remote heat).

In the development of stationary energy generation systems with internal-combustion engines, the reduction of emissions must receive increased attention.

Even conventional oil and gas-heating systems can be improved to increase efficiency. The performance of the heaters must be adapted to the smaller demand of buildings designed with energy conservation in mind. The refinement and testing of fuel-value devices is promising; by using them, tangible and latent heat contained in the flue gases can be extracted.

2.1.2 Industry

Future R&D work in the industrial sphere will continue to pursue goals of reducing product-specific energy consumption, of increasing the efficiency of used energy and of using waste heat. R&D emphasis is on:

- Reducing energy consumption of energy-intensive facilities, e.g. furnaces
- Development of new production methods, e.g. low-energy shaping methods, refinement of ceramic firing methods
- Increased use of power-heat coupling

- Development of systems to generate electricity from waste heat by using low-boiling hydrocarbons as working medium (Organic Rankine Cycle)
- Development of methods and systems to use industrial waste-heat sources
- Refinement of methods for more conservative use of energy in high-energy processes (e.g. hardening, vaporizing and drying).

Beyond these developments--which are of interest for a larger number of industries--possible solutions for energy-saving production methods can only be investigated to a limited extent. In these cases, for reasons of cost and competitiveness, a greater interest by industry itself can already be assumed. The financial means of the BMFT will thus be restricted generally to the determination of the energy flow in individual firms. A greater funding of demonstration projects is only justified if the introduction of energy-saving technologies to the production process would be hindered by excessive risks and the savings attainable by this technology is in the public interest.

The cumulative use of energy can be reduced for many products through adept selection of materials and production methods, and by use of recycling. But in order to do this, a knowledge of the energy use in producing pre-products is indispensable. Corresponding analyses should be made.

2.1.3 Transportation

In the FRG in 1980, 22.2% of the end energy and 32.0% of the petroleum was consumed in the transportation sector. Motor vehicle traffic today is almost totally reliant on petroleum fuels, whereas rail transport uses mainly non-petroleum electric drives. Important energy savings can be attained in this area on the medium to long term by shifting the transport services from individual vehicles to public transit. In addition, the different energy utilization levels of the individual transport systems offer a basis for technological improvements in energy conservation.

More rational energy use and diversification to non-petroleum energy carriers are thus important goals of the project to develop new transport technologies which are promoted by the Federal government in special programs.

Motor Vehicles and Road Traffic

The demand for high-mileage motor vehicles has increased due to the above-average increases in fuel prices in past years. The design of several prototypes has pointed up technical possibilities for doing this and accelerated activities by vehicle manufacturers. The funding of energy-saving technologies for vehicle transport is thus restricted to projects where the rational use of energy is a sub-aspect within the equivalent requirements for reduced exhaust and noise emissions and increased safety. The R&D work is centered on improving engine combustion by using electronic controls, on reducing

energy consumption through increased use of light materials, refined aerodynamic shape and reduced frictional loss. Energy savings can also be attained through refined traffic controls to speed the flow of traffic.

The almost complete dependence of individual transport on petroleum products can be reduced by alternative fuels from domestic sources, or at least from more reliable sources. In one project, the government is funding the testing of methanol, hydrogen and electric vehicles in road transport.

Public Transit

The specific energy consumption of public transit is much better than that of the individual motor vehicle. Technological R&D on rail transit systems is concentrated on the development of electronically controlled drives with continuous control for a low-loss operation. The emphasis of bus development is on new drive concepts, including those with regenerative braking and on the use of non-petroleum fuels.

Through light weight construction and shifting of heavy components from the vehicles into the road, and with new control and regulation systems for bus and rail, additional possibilities for saving energy can be pursued.

Rail

With the general electrification of the rail network, the railroad has created a non-petroleum, secure energy supply. To increase the attractiveness under the boundary conditions of a rational use of energy, the R&D work in the area of rail technology is aimed at improved aerodynamics of rail vehicles, increased use of light-weight components, refinement of electric drives with electricity regeneration into the mains, and the reduction of losses in energy transmission.

2.2 Techniques and Methods for Generation of Secondary Energies

In the area of end-energy consumption, the primary energy carriers are generally not used directly, but in the form of secondary carriers:

- electricity
- gases (natural gas, synthesis gas, sewer gas etc.)
- liquid fuels (heating oil, gasoline etc.)
- solid fuels (coke, briquettes etc.)
- remote (pipeline) heat.

The development of improved or new technologies for secondary energy carriers is concentrated on the following areas:

- use of waste heat for a remote-heat supply
- transport of remote heat
- storage methods, especially for gases and heat carriers in the supply system

-production, transport and storage technologies for new, secondary energy carriers like hydrogen, methanol and hydrogen-carbon monoxide mixtures generated by hydrogen reformation of methane ("Remote energy").

2.2.1 Waste-heat Utilization and Remote Heat

Due to the large fraction of low-temperature heat of the total energy demand, especially among households and small consumers, the technologies for rational heat supply are particularly important. In densely-settled areas, the heat supply to households via remote-heat networks takes this fact into account if it can use waste heat from thermal power plants and industrial production processes.

In pure electricity generation, the cooling water of the power plant has such a low temperature that it can only be used in special cases (Agrotherm, fish breeding, greenhouse operations). To use the waste heat for heating purposes, the power plant must be designed so that the heat can be released into a remote-heat pipeline at a temperature of more than 100 °C. This will reduce the efficiency of electricity generation, and this will have to be made up in part by additional power-plant capacity, but the total efficiency of the primary energy used in the power plant will be increased considerably.

The waste-heat from industrial high-temperature processes is presently used only in a few cases. The internal demand of industrial concerns for low-temperature heat is usually so low that waste heat from high-energy processes can only be used when connected to a sufficiently large remote-heat line.

Previous Funding of Remote Heat and Waste-Heat Utilization

In previous years a series of studies, research projects and demonstration programs were funded within the framework of the first energy research program.

In the "Major Study on Remote Heat" the extent to which the remote-heat supply in the FRG could be expanded under economic conditions, was explored. For four areas (Berlin, Mannheim/Ludwigshafen/Heidelberg, the majority of the Ruhr area and Cologne/Bonn/Koblenz) detailed plan studies were prepared. The result of this remote-heat study was a heat atlas for the FRG which marked the regions suitable for the expansion of remote heat. A computer program is available to determine the "remote-heat potential" under various boundary conditions. In addition, the study contains a series of technical recommendations.

In the "Major Study on Remote Heat" the possible savings in foreign exchange, the attainable reduction of pollutant emissions and the effect of an accelerated expansion of remote heat on the job market were determined.

The Remote-heat study soon became a major reference work used in practically all remote-heat expansion projects.

The potential for expansion of remote heat is quite sensitive to the costs for transport and distribution of the heat. In one program study which examined systematically all domestic and foreign systems in use at that time, a check was run to see which R&D work could improve the economy, service life and reliability of remote-heat systems. This study was the basis for a series of successful research projects.

By means of remote-heat linkage systems, the prerequisites for the inclusion of various, especially industrial, waste-heat sources was created. Thus, the supply reliability is improved. The BMFT has supported since 1975, several demonstration projects which demonstrated that the problems of industrial waste-heat utilization can be mastered in connection with remote-heat linkage systems. These demonstration projects in the Ruhr area and in the Saarland provide valuable information about the economy of such large projects. The start-up losses of the demonstration projects were covered in part by funding from the BMFT.

The extension of the remote-heat supply is another of the important energy objectives of the Federal government. Thus, the funding of research, development and demonstration projects in the present energy research program will continue to be of importance in the heating sphere.

Heat Generation

There are some quite different potentials for heat extraction and injection into the remote-heating systems. In addition to the use of large heat power-plants, the economic considerations of small, standardized coal heating plants will have to be checked.

The extraction of heat from nuclear power plants for remote heating networks was investigated in several areas. The study results are promising.

The most important research tasks in the area of heat generation are:

- Cost reduction, automation and optimizing of power-plant systems using hard coal
- Potentials for heat extraction from existing power plants.

Heat Transport and Distribution

For the economical transport of heat over large distances, limiting distances of 20-30 km were found in the Major Study on Remote Heat for large heating outputs of 1000 to 2000 MW. Due to the super-proportional price increase of fuels and the on-going technological development, one can assume that the economic range of heat transport will increase to longer distances or to smaller heating output. Thus it will be possible to incorporate smaller and medium cities of built-up areas into a regional remote-heat supply system during the accelerated expansion of remote-heat networks.

In recent years systems of channel-free line installation have been developed and introduced to reduce the heat distribution costs. In particular to include low structures in regions suitable for remote-heating, this trend should be stressed in future, and developments in the Scandinavian countries can provide a model.

The following research projects may contribute toward a more favorable structuring of transport and distribution of heat:

1. Pipeline-like laying of lines
2. Compensator-less laying
3. New thermal insulation systems
4. Use of chemical additives to prevent pipe friction losses
5. Monitoring of large heat-transport systems
6. Investigation of tunnel methods for parts of large transport lines, to solve right-of-way problems under extreme conditions in a megalopolis
7. Shaftless laying of filling lines.

Besides the heating of settled areas, the inclusion of single-family dwellings in the remote-heat supply is a new task of remote heat supply arising from energy price movements in the FRG. Above all, low-cost, small house stations should be developed.

2.2.2 Energy Storage

The storage of thermal energy is a fundamental problem of energy engineering. Of particular interest is the long-term storage of low-temperature heat. In this manner, the waste heat from thermal power plants or industrial processes could be used year-round.

Heat-transport lines could be operated year-round with a reservoir near the user; they could thus be smaller and of less expensive design. Solar energy could also be stored in summer and used in winter.

These advantages are countered by the main difficulty of building long-term stores at manageable costs (insulation requirements, safety, various technical difficulties, space requirement).

The primary application is the storage of low-temperature heat for heating purposes in consideration of the following systems:

-Remote heat:

Meeting peak demands through heat stores, bridging low-demand times of power-heat coupling, reducing the reserve capacities and increasing the heat portion from the power-heat coupling (daily, weekly stores). Heat regeneration and storage. Use of industrial waste heat and of excess heat of the summer power-heat coupling (seasonal storage)

-Solar energy:

The direct use of solar energy with daily storage can only meet

about 10% of the total annual household heating demand. A larger percentage can only be attained through annual storage. Due to the large thermal losses for small storage units, a large, central store can come into consideration for long-term storage.

Previous Funding of Heat Stores

Technical and economic feasibility studies of various long-term storage systems, especially of storage lakes and aquifers (storage of water is porous material), were performed. In laboratory tests the long-term behavior and other properties of suitable insulating and compaction materials were tested. Latent storage of heat seems promising since smaller heat losses occur and greater storage densities are attained. In several projects the materials suitable for this were investigated.

In a planned, large project on storage of heat in a storage lake to operate in connection with a remote-heat network, several IEA member states desired participation. Due to the large technical difficulties, connected in part with the needed reduction in ground-water level, the project had to be terminated. Nevertheless it is necessary to test the experiences and knowledge gained in pilot and demonstration projects in the future.

Research Tasks

There have been four possible solutions for the long-term storage problem:

- container storage: limited in size, thus probably too expensive
- storage lake: Investigations on feasibility have been performed
- aquifer store: high costs, probably similar to the storage lake.
Advantage: Use of storage surface area is less problematic. Disadvantage: Poor utilization of storage space, probably certain operating disadvantages.
- Shell-segment store: If it is hoped that problems occurring with the storage lake (need for reducing ground-water level, difficulties in development of long-term insulation layers) can be more easily mastered by metal linings of the storage basin. But it is questionable whether the same storage content can be attained.

In addition, work should be continued in the area of short-term heat storage. Besides latent-heat storage, thermochemical stores are of interest; these promise fundamental advantages compared to water stores: Much higher energy densities and practically non-loss long-term storage. In addition there are various potentials for operation as (chemical) heat pump, heat transformer, possibilities for use in heating and cooling, use of lower temperature, solar heat and waste heat from power plants.

In Germany the thermochemical storage based on the Zeolith-water system has been investigated in a prototype system. Although the chances for an economical, seasonal storage are very low for

the Zeolith water systems under investigation today, work must be continued in this area since decisive improvements are possible (substances with higher energy densities, improvements of operation).

Storage systems for electrical energy are important not only for equalizing the energy demand and availability for electric solar and wind generators, but also for the electrical drive of highway vehicles and for the storage of small quantities of excess electrical energy. In particular, storage batteries are suitable for this. The funding emphasis in this area in coming years will be on:

- the development of the sodium-sulfur battery as the most interesting medium-term solution for a high-energy store
- establishment of various other classical or futuristic systems, e.g. the lithium-sulfur system. Included herein is a certain amount of fundamental research in order at least not to miss any possible, future options, and to have a scientific foundation for the technical work.

The sodium-sulfur battery has moved into a stage where we have to take the step from the laboratory phase into the development phase. It promises a 2-3 times greater energy density than the lead battery. Significant improvements are still possible to this system and alternative ceramic electrolytes are imaginable.

The lithium-sulfur system comes closest in performance data to the sodium-sulfur system. Of course, it is not yet so far advanced as the sodium-sulfur battery, but does have certain advantages due to its relatively simple design and also offers possibilities for its technological creation.

2.2.3 Hydrogen and Remote Energy

In the area of hydrogen production, originally three lines of development were followed: The so-called thermal cycle process, new electrolysis techniques and the hybrid processes. The available results have shown that the thermochemical cycle process cannot fulfill the hopes set on it. Thus, funding is concentrated on the high-temperature vapor-phase electrolysis. In this method, steam is split into hydrogen and oxygen in a cell containing a solid electrolyte; the needed energy is input thermally and electrically. A total efficiency of over 40% results, whereas the efficiency of conventional electrolysis is about 25%. Additional research on hybrid methods in which electrical energy and heat energy are linked together at high temperatures, is being funded by the German Research Union in a special research project.

Within the frame of the project "Nuclear Remote Energy (NFE)", the development of a method is being funded where energy can be transported over longer distances in chemical form through linkage of a heat-consuming and heat-releasing chemical reaction.

Methane is converted into a gas mixture composed mostly of CO and hydrogen after addition of steam and using process heat from

high-temperature reactors. After cooling to ambient temperature, this gas can be fed over long distances into heat-consuming regions. Here it is recombined into methane in a methanation plant with liberation of the input process heat. The methane is fed back in a second line to the precess-heat generator, where it is used anew for the conversion. In this closed system, the useful energy for the consumer is released similarly to electrical energy without any negative environmental influences. Compared to electricity, the possible advantages lie in a higher efficiency of conversion of primary and secondary energy, and in the storage ability. Compared to remote heat, the positive potential of loss-free transport over longer distances is important.

The NFE project is performed jointly by the KFA Jülich GmbH and the Rheinische Braunkohlewerke AG(RBW). After preliminary tests with a small plant, the Adam II pilot plant will go into operation at the end of 1981.

3. Coal and Other Fossil Fuels

The world supplies of coal exceed all other fossil fuels. The FRG has large primary energy supplies of hard and soft coal only. The coal policy of the Federal government has led to a stabilization of delivery and use of German hard coal at around 90 million tons of hard coal units (SKE). R&D in the mining sphere has led to a considerable increase in efficiency in hard coal mining. The underground working conditions have been improved.

Soft coal continues to be an important pillar of German electricity generation. Today, 55% of the electricity in the FRG comes from hard and soft coal. By 1995 the use of German hard coal in power plants will increase to 45-50 million tons/year. In addition to electricity, coal in future will be used increasingly to meet industrial heating needs and for remote-heat generation to replace heating oil or natural gas.

Whether the substitution of other energy carriers by coal will tend to cause greater pollution depends on the scope and technical equipment of both the additional coal power plants, and on those power plants which replace old facilities. For example, the report of the Federal Environmental Office "Air Pollution by Sulfur Dioxide" of 1980 comes to the conclusion that the total SO₂-emissions from combustion processes will probably decline by almost 20% between 1977 and 1990 (assuming additional exhaust scrubbing in coal power plants). In addition, existing reduction techniques may become more effective. Due to the high costs for the use of hard coal, special attention must be paid to economic considerations.

Environmental protection and economy of coal utilization are goals of the new power plant and firing techniques. The various types of fluidized-bed firing are important cases where the coal can be used both for generation of process heat in industry and for

public electricity and remote-heat supplies, with a relatively low emission of sulfur dioxide and nitrogen oxides. In order to reduce emissions of other pollutants as well, corresponding development work is underway with the goal of using ballast coal.

In a broadly-based study, the environmental effects of increased coal use in the FRG have been investigated.

Coal has a large potential for enhancement:
The possible range of products extends from electrical energy to gaseous and fluid energy carriers and chemical raw materials, down to metallurgical coke. Thus it is generally expected that coal will be in greater use worldwide and that new technologies for coal utilization will play an important role. The coal enhancement program should enable German industry to retain its international lead in this sector and permit access to low-cost foreign deposits through our technology export.

Similarly, R&D on improved petroleum pumping (tertiary recovery) especially the building of a heavy-oil center, should improve the technical capability of German firms and make them into competent and desirable partners in the extraction of difficult to exploit deposits.

3.1 New Power-Plant and Firing Techniques

Power-plant engineering in the FRG has reached a high level. Over the last 30 years a rapid technical development characterized by a transition to larger output plants, has been completed.

The funding of new technologies for coal power plants and large firings has the primary goal of combining the requirements of environmental protection, which have become more acute since the beginning of the 1970s, with the requirements for an economical and energy-saving operation. Technologies will thus be developed for small, non-polluting thermal power plants set up near consumers which can deliver high-efficiency electricity and remote heat.

3.1.1 Components for Environmental Protection

Using funds from the Future Investments Program, in 1977 a large number of projects was undertaken with the goal of developing components and system assemblies to prevent emissions of sulfur dioxide, nitrogen oxides and problems connected with this. The final objective was to be able to use these technologies in new power plants after a relatively short development and testing time. This component development proceeded successfully throughout. Some of the developments are already used commercially and are moving through the approval process.

Solutions for flue-gas desulfurization (scrubbing) yielding recoverable end products and operating with a minimum of waste water are sought, since the improvement in air quality is not to be purchased at the expense of waste water and disposal problems. One of

the BMFT-supported scrubbing methods operating without waste water with recoverable end products (ammonium sulfate fertilizer) will be used in a new 475 MW thermal power plant in Mannheim. The plant is currently under construction.

A good example for a practicable environmental technology is the successfully tested stepped burner for coal-dust firing which can reduce the formation of nitrogen oxides by more than half without additional energy consumption and without significantly increased costs. Prototypes were tested both for dry firing and for fusion firing. Operators and boiler and burner manufacturers are taking this development into account in all currently planned facilities, and for those already under construction where possible. Due to the results of these developments, emission standards for nitrogen oxides are now in preparation for the first time.

In the Völklingen model power plant, several of these new technologies are used to prevent pollution from coal power plants. Since the scrubber system (which completely cleans the flue gas) is located in the cooling tower, the smokestack can be eliminated. In the power plant a dust firing is combined with an atmospheric fluidized-bed firing. Thus lower-quality coal can be used. A hot air turbine is driven via the fluidized-bed firing and it generates 35 MW of the total 230 MW power output. The efficiency of the model power plant is higher than conventional power plants. The plant operates in thermal-power linkage. The tangible heat of the flue gas is also used for remote-heat supply via a fluidized-bed heat exchanger. The thermal power plant is connected to the remote heat system of the Saar. The reheating of flue gas is omitted since it is taken along in the lift of the cooling tower.

Long term the development of new methods for heat and electricity generation from coal is desirable, provided the content of sulfur and nitrogen oxides in the flue gases can be reduced by the process operation.

Additional goals are the reduction of plant size to reduce investment costs, and an increase in efficiency and utilization. Finally, smaller designs of the new systems will be used near population centers, where they can be used both to generate heat or in power-heat linkage.

3.1.2 Fluidized-bed Firing

Fluidized-bed firing is suitable for production of heat and electricity near housing districts or in industrial facilities. It can replace plants operating generally with petroleum or natural gas.

The advantage of the fluidized bed consists in its relatively simple and low-cost desulfurization, even for small units, through the addition of powdered limestone. In addition, lower quality coal can be used.

Through the relatively low combustion temperatures there also result relatively low nitrogen oxide emissions. However, the fluidized-bed firing, especially when using ballast coal--in contrast to conventional, large firings, should receive special attention regarding the pollutants like hydrogen halides and organic compounds. The generally higher expulsion of dust and a higher fraction of heavy metals and carbon in the dust, do require an increased effort for dust removal.

The pressureless-operating fluidized-bed firing is almost ready for market introduction. Two demonstration plants have been tested, two others are in planning or under construction. One of these plants will have a circulating fluidized bed which is expected to give additional advantages like better burn-off and even lower nitrogen oxide formation. The largest of the plants has a rated power output of 230 t fresh steam per hour.

The maximum power size for fluidized-bed firings must still be determined. The efficiency and environmental safety of this technology shall be refined through the development of new components and modes of operation.

3.1.3 Advanced Systems

The advanced systems for hard-coal liquifaction are characterized mainly by the potential for sulfur-removal right in the power-plant process, thus permitting elimination of the complicated scrubber. In addition, the gas turbine opens up the coal so that efficiencies of more than 40% can be achieved via the combined gas/steam turbine process.

The lines of development followed in the FRG are power plants with:

- pressurized fluidized-bed firing
- partial or complete pressure gasification of the coal.

A few years ago, work began on a project for pressurized fluidized beds. Their development is still a few years behind the pressureless version.

The domestic work on pressurized fluidized-bed firing is being supplemented by a project within the frame of the IEA. The partners in the building and operation of the 80 MWth plant in Grimethorpe/England are the USA, Great Britain and the FRG. This pilot plant began operation in 1980. Both the building and operation of the plant have the participation of German firms.

For a combination of fluidized-bed firing with a gas turbine, pressures of about 10 bar are needed. An intermediate step placing lower technological demands would be a fluidized-bed with a pressure of several bar. At this pressure the work needed to maintain the fluidized bed can just be generated. In the thermal power plant at the Univ. of Aachen, a prototype of this technology using grate-firing

boilers is in operation, so that the efficiency of the new technology can be compared to conventional designs.

In an initial study, a 250 MW -power plant with gas turbines and pressurized fluidized-bed firing was investigated. These engineering investigations should be continued for other commercial power plants with pressurized fluidized bed or with pressurized coal gasification, in order to get a handle on the concepts and technical demands. Several existing coal gasification methods are quite suitable for a combination with a power plant. After successful component development, the construction of prototype power plants with this technology will be possible.

In the coal-conversion process, the coal is only partially gasified. Gas and residual coke are used separately in the power plant. A combined gas/steam process is intended. Through the use of the residual coke, the carbon can be better-utilized than if the coal were completely gasified. For this coal-conversion process tailored specifically to the needs of power plant engineering, a pilot plant with a throughput of 10 t coal per hour is being built.

The use and success of this advanced power-plant concept will be affected decisively by progress in gas purification and gas-turbine development. Methods are needed by which flue gas or combustion gas can be purified at high temperatures and pressures. For dust removal suitable electrostatic or mechanical filters are being developed. The removal of sulfur and other pollutants at high pressure and temperature causes additional difficulties. Work on these key technologies is being emphasized.

Efficiency losses and weakpoints in gas purification can be compensated perhaps, by appropriate development of gas turbines. For the fluidized-bed firing a gas turbine is needed which can withstand large amounts of dust.

The development of high-performance gas turbines for temperatures of 1300 °C and more, is aimed at a combination of a power plant with the technology of pressurized coal gasification. Through the testing of suitable burners and modes of operation it will be assured that nitrogen oxide formation stays as low as possible.

Presuming a smooth technical development, power plants with pressurized fluidized-bed firing or with pressurized coal gasification could be of commercial importance after about 1990.

3.1.4 Coke Production

About 40% of the hard-coal production in the FRG is used today for the production of coke for metallurgical purposes. Blast-furnace coke is unlikely to be replaced long-term, by any equivalent reducing agent, since it is characterized by good lumpiness and by pressure and friction resistance at high temperatures. Development activity by Bergbauforschung GmbH is aimed initially at improving the conventional, horizontal-chamber method; this effort is supported by the Federal government and by the EEC for Coal and Steel (EGKS).

In the Saar mines, compression engineering on coking of coal is being refined. In this regard, dry-cooling of coke is particularly important, with the goal of regeneration of the energy used in the coking while simultaneously reducing the pollution. For an integrated smelting plant the coupling of dry-cooling of coke and coking-coal preheating with blast-furnace gas, is being investigated in a pilot plant.

3.1.5 Direct Combustion and Garbage Recovery

To supply heat to households and small consumers, coal is used only to a small extent. The supply of housing districts with remote heat from coal-heating power plants will meet the comfort needs of the consumer and at the same time improves the emission situation in the supplied area through the elimination of individual firing. In order to make coal competitive for this use, fully-automatic boiler systems must be developed. This will greatly reduce the wage-portion of costs for coal-fired plants. With a specific development for the combustion of a mixture of anthracite with lignite in central heating units, a comfort will be attained which equals that of oil-fired systems. The emission and immission problems will receive a great deal of attention in this regard.

In order to use the energy content of lower-value wastes, methods are under development for a non-polluting and economical burning, gasification or pyrolysis of garbage. This use will be direct via the generated heat, or indirect through the materials produced in the process, e.g. purified gas.

In another project on a small pilot scale, lower-quality coal is converted to combustible gas through the addition of trash. This method can be important where waste-coal and trash are available in sufficient quantity and the product gas is used on the heating market. For all the named methods, the problem of air and water pollution deserves particular attention.

3.2 Coal Upgrading

The successes achieved since 1974 with modern methods for upgrading coal and the drastic increases in petroleum prices resulted in the decision of the Federal government at the beginning of 1980 to demonstrate the most promising methods within the framework of a coal upgrading program. The large-scale conversion of coal still requires considerable R&D efforts to become economical and to solve the environmental problems. The relatively high investments are justified from the standpoint of energy and industrial policy:

- Coal upgrading should begin the process of reduced reliance on imported oil. However, it will achieve greater significance only for the long-term--even through foreign plants on low-cost deposits.
- The FRG must act so that the international capabilities of German producers will be maintained or improved in this future technology.

The construction and operation of coal upgrading plants can simultaneously create the basis for additional industrial growth and for additional employment, since the number of coal upgrading plants will probably increase in coming decades. This will have technological effects in related areas.

Due to their pollution, coal upgrading plants will require the approval by the Federal Emission Law. In addition, the waste-water lines are subject to the Water Management Law. The plants for elimination of wastes require approval as per the Waste Disposal Law (proposed). For a coal gasification plant, an approval has already been issued in compliance with the Federal Emission Law. As for the other coal upgrading plants, the companies are assuming that all environmental requirements can be met--even though with considerable additional investment. Particular attention will be given the R&D policy areas which are not yet covered fully by existing standards.

The companies have presented planning studies on the technology, economy, siting and environment for seven coal upgrading projects within the frame of the coal upgrading program.

As these planning studies show, the economic risks resulting from the coal gasification projects based on German or imported hard coal are so high, that the completion of these projects in the near or distant future is quite unlikely without State aid. The Federal government has thus provided the following aid: Investment cost allowance up to 40% (in well-founded cases, up to 50%); when using German hard coal, price differentiation to foreign coal of max. 60 DM/t SKE for five years. In an application procedure, the most promising projects will be selected for funding on the basis of energy and industrial policy. In the budget of the Ministry of Economics for 1982 and in medium-term financial planning to 1985, a total of 1 billion DM will be allocated. The mining states are basically willing to participate in the coal assistance.

Industry has suggested three large projects for hydration of hard coal and one for lignite hydration. For the large plants for hard-coal hydration, extensive planning studies have been prepared. Due to the large space requirement, we have only a limited number of possible sites.

The basis for coal liquifaction is the refinement of the IG-Farben process for direct hydration, which is not yet able to handle useable heavy oils and refinery residues.

The liquifaction of hard coal is not yet economical, even when using imported coal. The production of one liter of gasoline from German coal would cost about twice as much as production from petroleum; thus these plants require considerable financial assistance.

The Federal government will probably decide in the second half of 1982 on additional funding of large-scale coal liquifaction plants after evaluation of the planning studies. The granting of a hydration preference will be examined for the operation of such plants. To reduce the technical risks of the large plants, a development program will be performed for the testing of particularly critical components.

3.2.1 Coal Gasification

A prerequisite for success of the demonstration plants for which detailed feasibility studies have been prepared by industry within the frame of the coal upgrading program, is the development of appropriate system components and continued operation of the pilot plants. Considerable funding is needed in coming years for this work accompanying the prototype systems.

In the FRG there are presently five pilot plants supported by the government for coal gasification or methanation of coal gas:

Operator	Technology	Location
RAG/Ruhrchemie	KSV-process (Texaco)	Oberhausen
Ruhrgas/RAG/Steag	Lurgi "Ruhr 100"	Dorsten
Saarbergwerke/Dr. Otto	Saarberg-Otto gasifier	Völklingen
Rheinbraun	High-temperature Winkler	Frechen
Thyssengas	SNG-production using the Comflux process	Oberhausen

The first 3 pilot plants are designed for the use of hard coal; the project of Rheinbraun is for soft coal. The product is synthesis gas, i.e. a mixture of carbon monoxide and hydrogen. The production of methane SNG from synthesis gas is being tested on a pilot scale by the Thyssengas process.

In addition, a smelter-related coal-gasification method is being funded in the coal gasification process in the iron-bath reactor. The advantage of this method is that petroleum and natural gas can be directly substituted in the smelting industry by the product gas, without complicated after-treatment.

Besides the conventional coal-gasification methods, two methods of combining coal gasification with a high-temperature reactor (HTR) are being funded. One part of 30 - 40% of the coal burned as conversion energy in conventional methods, could be replaced by nuclear energy in this case. Test facilities not using nuclear process heat are in operation by Rheinbraun and Bergbauforschung. This technology is still connected with a large economical risk. Operation of a large scale facility is not expected before the year 2000. The method of Rheinbraun for hydrating coal gasification can also be used without HTR to generate SNG. A pilot plant with a throughput of 25 t/h rough brown coal will go into trial operation by mid-1982.

The Federal government intends to support the development of new and improved coal gasification technologies in the future. Besides the pilot plants supported by the government, one plant without public funding and another one supported by the state of North-Rhine Westfalia are under construction.

3.2.2 Coal Liquefaction

One of the goals of the coal upgrading program of the Federal government is the timely production and economical introduction of coal liquefaction technology under aspects of industrial and energy-supply policy. The following parameters will play a role, and they generally cannot be affected by the government:

- Profitability of the method (measured by the movement of oil and coal prices)
- Developments in competing technologies, domestically and abroad (coal upgrading in USA and Japan, heavy oil in Venezuela, oil shale and sands in Australia, USA, Brazil, Canada and China).

The R&D work on coal liquefaction should create the prerequisites for a construction decision on large industrial plants.

Coal liquefaction development still lags behind that of coal gasification. At present, three laboratory facilities are in operation for hard coal hydration (Saarber, RAG, VEBA) and one for soft coal hydration (Rheinbraun).

Two pilot plants are in operation. One smaller one with a throughput of 6 t coal/day is operated by Saarbergwerke, and one larger facility with a throughput of 200 t/day by RAG and VEBA.

Due to the level of required investments for coal liquefaction plants, a stepwise procedure is intended. Thus, at first the following preliminary developments are being funded before construction of a large-scale plant:

- A 4-year R&D and test program for critical system components: Reactor vessels, hot-gas treatment, vacuum residue gasification, solids transport pumps, valves and armatures.
- After a positive decision by the Cabinet on large-scale coal liquefaction plants after the beginning of 1982, the technical planning will begin, and if a positive building decision is given, detailed construction can begin by about 1984.
- Parallel with the engineering work, site-planning and locating procedures will be performed.
- In connection with this are accompanying R&D work--which will have to be increased considerably over today's level--on the analysis and management of pollution due to the planned facilities.

Besides the work directed toward the building of large plants, new lines of development, e.g. the conversion of methanol into gasoline, or high-pressure hydration will be taken up and funded.

3.3 Exploration of Deposits, Mining Technology, Processing

The innovation projects funded by the government in hard-coal mining are intended to accelerate the use of modern techniques in mining. Preliminary tests on improved yields from German coal deposits led to positive results.

The hard coal veins of the Ruhr valley move out to the North at increasing depth to beneath the North sea. Consequently, the mining must proceed to ever-greater depths. Due to the resulting soil pressure and increasing temperature, problems associated with underground mining are increasing. Thus, the introduced technology must be continually improved and developed.

With regard to the high soil pressure, the safety and economy of coal mining at great depths, a new mining system is used--the NOET-method (New Austrian Tunnel Excavation Method). Even today it turns out that there are possibilities for a controlled stoppage of all mountain movements, even over larger route cross-sections and zones of disturbance by using anchors and sprayed concrete.

The development of a new extraction method using high-pressure water (HDW) has been successfully concluded. The first underground tests provided very good results.

3.3.1 Exploration of Coal Deposits

In order to answer the question of the long-term availability of domestic hard coal, we need a systematic determination of reserves*. In order to do this, we need specific information about the deposits like size, depth and coal quality, secondary rock formations and tectonics. An evaluation of this data also provides information about whether the development of new extraction techniques seems necessary.

In deposit exploration in the zone in front of the face, the primary methods are those of preliminary zone exploration. Seam seismology, pulse-radar and horizontal drilling methods are examples of such technologies.

3.3.2 Mining Technology

German hard-coal mining has made considerable progress in recent years--due not least to the R&D funding by the Federal government. Internationally however, German mining technology is highly questionable. In the future, R&D work will concentrate on specific problems.

*"Reserves" are that portion of the total resources (total supplies) which can be recovered technically and economically.

We are dealing primarily with technologies which permit mining of coal deposits under difficult geological conditions.

In spite of these successes, there is still a considerable mining demand for new technologies which make working conditions underground safer and more humane. Special projects of the "Humanizing of Working Life" program will contribute toward this goal.

A large part of the total supplies is found in steep sloping coal seams which at present are almost impossible to recover because there is no suitable technique for its economical extraction. Thus, the development of new, e.g. supportless methods, or the adaptation of proven support systems and equipment to vertical deposits is needed. Parallel with this, the advance systems must be adapted to the conditions of steep deposits for a fast and economical exploration of new deposit sectors.

The unused, residual surfaces of a mined coal seam today make up to 50% of the seam surface. Consequently, the utilization of recoverable seams is low. Therefore, special mining systems should be developed for residual and peripheral deposits.

For thin seams which also make up a significant portion of total supplies, mining techniques with automation and high reliability should be developed.

Whereas the machines for driving into seams have been continually improved, today the necessary supporting work is done almost entirely by hand. By means of a coordination of the needed work steps to each other, the efficiency of the driving machines can be increased. The development work will help to open up new deposits more quickly and at lower cost in the future.

The great depths from which coal will be mined in the future require the development of new methods for mastering the mountain pressure. Included here are investigations on new support techniques like the development of new roofing and the use of steel-fiber reinforced sprayed concrete. Parallel with this, new construction materials have to be found which can withstand the mountain pressure and climate at great depths (up to 1,600 m).

Since the underground mine workings are becoming increasingly large, universal transport means must be developed.

Also, data acquisition, transmission and processing systems are needed by the mining industry.

3.3.3 Coal Processing

Modern, low-cost conveyor methods lead to decreasing quality of the rough conveyed coal, e.g. to increasing water, sulfur and dross content, higher percentages of fine(st) grains and movement of coal with a higher level of intergrowth of coal, dirt and sulfur. This

requires new processing methods to produce marketable products or to adapt them to the quality demands of the market.

With the increasing use of cutting extraction in mining, the fine-grain percentage of the rough cut coal is increasing. This fraction had been removed by flotation. In future, the finest coal will be removed directly from the rough moved product.

3.4 Underground Gasification

A considerable part of presently unrecoverable hard coal could be mined through development of new extraction techniques. This includes chemical crushing, liquifaction and gasification underground. Of these methods, underground gasification is the most feasible.

In the Belgian-German field test begun in 1979 in Thulin (Belgium), the technical feasibility of underground gasification will be tested. Accompanying investigations and laboratory tests are being continued in order to test the suitability of process variants and to apply the results of the field test to other mining conditions.

3.5 New Methods for Extraction, Separation and Storage of Liquid Hydrocarbons and Natural Gas

Under consideration of the short supply of petroleum and natural gas, a better utilization of deposits through new extraction methods and the use of unconventional energy carriers (heavy oils, tar sands and oil shale) by means of R&D efforts are of great interest. In general, in the extraction of mining deposits, pollution of agriculture, nature and of the water balance are unavoidable and this has to be weighed against the potential supply contribution and our energy policy. In appropriate R&D projects, a minimizing of such effects is always desirable.

3.5.1 New Methods for Extraction and Separation of Heavy Oils, Tar-Sands and Oil Shale

A significant, unused energy potential is found in the hydrocarbon content of oil shale and heavy-oil deposits and tar sands.

Due to the importance of these energy reserves, construction of a center for the extraction and separation of heavy oil and bitumen was begun by the VEBA-Oil AG in Gelsenkirchen. Experience in the area of exploration and production of heavy oils has not been available in the FRG to a sufficient degree. However, more extensive know-how is available from the related area of processing of heavy residues from petroleum refining.

The goal of the planned R&D project is to perform systematic work in the areas of exploration, production and separation using real projects, e.g. on deposits in Canada, USA and Venezuela--after

collection and evaluation of existing data and information. A new method will be developed for the use of oil shale, with special emphasis on export considerations.

The mining and extraction of petroleum and natural gas from undersea deposits requires more intensive R&D work, especially in deeper water and under extreme environmental conditions. Through specific funding the German marine industry should be able to develop and produce marketable instruments, systems, components and software systems with a view toward improving the German energy supply. Finally, knowledge will be expanded about potential offshore reserves of hydrocarbons by funding of prospecting and exploration efforts of German institutions, including the refinement of methods necessary for this exploration. The measures needed to achieve these goals will be contained in the "Fourth Major Program on Marine Research and Engineering in the FRG".

3.5.2 New Prospecting and Exploration Methods

With the methods of applied geophysics, structural pictures of the subsoil can be generated at depths up to 6 to 8 km. In the search for hydrocarbon deposits in regions of complex tectonic relationships, standard methods of prospecting and exploration will fail however. The refinement or new development of seismic methods is thus an important goal of the funding. In addition, other geophysical methods, like magnetotellurics, geoelectrics or in-situ drill-hole measurements can interact to improve the validity of estimations of the nature of the subsoil. Geochemical methods and isotope engineering can increase chances of success in the explorations for hydrocarbons.

To refine the prospecting methods, work is needed in the following areas:

- direct detection of hydrocarbons and exploration of the lithology by seismic means
- systematic incorporation and refinement of ADP-supported methods for detection and interpretation of geologic structures
- field methods and refinement of techniques and interpretation methods of other geophysical methods
- geochemical and geomicrobiological methods for prospecting and classification of heavy oils and petroleum
- new deep-drilling techniques.

3.5.3 Improved Petroleum and Natural-gas Transport

The level of recovery of a deposit depends on the mobility ratio of the gas/liquid phases within the pore spaces of the deposit rock structure, and on the boundary tension prevailing at the phase boundary.

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R&D projects serve to develop suitable chemical flow additives to reduce the boundary tension of water/oil and to increase the viscosity of the flood water. The reduction of oil viscosity by flooding with carbon dioxide can lead to a considerable residual oil mobilization in deposits with high temperatures and salt contents. Slightly-permeable, deep gas deposits can be made permeable by generation of cracks in the rock ("Frac treatment").

3.5.4 Underground Storage of Petroleum and Natural Gas

To secure the energy supply during times of crisis, considerable storage capacities were created in the FRG for petroleum and natural gas. To equalize the delivery and consumption, a number of buffer stores have been established, especially for natural gas (pore storage in aquifers and old gas deposits, and use of caverns in salt mines in North Germany).

The establishment and operation of an underground store requires exploration of the geologic conditions, a careful mining calculation of the available cavity and continuing monitoring of its shape (cubature).

The mining-mechanical behavior of salt formations requires special modes of operation to achieve the longest-possible utilization of the cavern.

4. Renewable Energy Sources

Among the renewable energy sources are solar radiation and ambient heat, energy of running water, from biomass, wind energy, wave energy and sea heat, all of which originally obtain their energy from the sun. Geothermal and tide energy are also renewable sources. The massive increase in energy prices since 1973/74 also moved these energy sources more into the foreground, since they could provide a correspondingly increasing contribution to the energy supply if energy prices continue to rise.

With the previous funding of energy research, the entire spectrum of renewable energy sources was investigated and the development of techniques for their utilization was performed on a broad basis. This led to their value being more accurately estimated today, than at the beginning of the research work.

The renewable sources naturally have a low energy density. This means that the energy has to be collected over large areas with a large technical effort. These sources are thus suitable primarily for decentral supply to small consumers, and less for densely populated zones with high energy demand.

Many renewable sources are not constant over time (solar energy depends on the time of day and year). For their use, energy stores are important. There are still many technical and economic problems in this regard, especially of long-term storage.

If the supply and demand occur at the same time or if simple interim stores will suffice, like e.g. for outdoor swimming pool heating in summer, drying of agricultural products, heating with wind energy in windy areas, then regenerative energies can be used.

Through suitable architectural structure and modern construction (thermal insulation) of buildings, the energy demand can be reduced considerably. In this regard, the passive solar energy use can make the greatest contribution to the use of renewable sources of energy in the FRG--even under our climatic conditions. The use of renewable energy sources should thus be included in practically all cases with measures to reduce the energy demand in order to minimize costs.

Among the active systems, the heat pump is particularly important; it can use ambient heat for heating buildings.

Large facilities to use renewable energy sources, like solar-thermal power plants, solar supply units with high tracking accuracy or systems for alcohol production from wood, have an economic feasibility only over the long term.

Methods for the use of solar energy for direct generation of hydrogen or electricity via photobiological, photochemical or photo-electrochemical conversion are still in the stage of fundamental research. The extent to which valuable contributions to the energy supply will be possible by these means cannot be judged today.

The use of sea heat and of wave and tide energy cannot provide any contribution to the energy supply of the FRG due to our geographic and climatic conditions. The world-wide useable potential is small.

Parallel with the development of technology, investigations on a possible environmental impact are being performed. The problems of using biomass, e.g. energy plantations, require special attention. These problems have been addressed by the Council of Experts for Environmental Questions (SRU).

4.1 Systems and Concepts

The fluctuating availability of individual, renewable energy sources (e.g. sun, wind) and the potentials for decentralized energy supply in remote, thinly populated regions, suggest a mutual interaction between the supplier and consumer to investigate all available energy sources. Such integrated energy supply systems may contribute toward the economic use of the locally available energy potential, especially in rural regions, through combination of various systems. The technical complexity, reliability and applicability of the corresponding technological solutions should be determined and tested experimentally.

In countries with generally decentral energy consumption and favorable climatic and agrarian economic conditions, the renewable energy sources can over the long term, become an important part of

the energy supply. Thus, the development of technologies and energy supply concepts adapted to the needs of such countries, is also a part of the development goals of this program.

The application of experiences obtained in Germany and in addition, the preparation of special solutions on the energy sector, already presumes a close cooperation with the affected countries right in the R&D stage. Thus, in the framework of bilateral agreements on scientific-technological cooperation, e.g. with Mexico, Egypt, Indonesia and China, a series of projects was begun in which the future energy supply concepts to rural areas have been taken up. Of primary interest are solar, wind and bioconversion plants to generate hot water, passive use of solar energy in buildings, heating and cooling, water treatment of drinking and irrigation, generation of process heat for refrigeration of foods, drying of agricultural products and generation of electricity.

4.2 Heat from Solar Energy

In the first energy research program, practically all techniques were developed for conversion of solar energy into heat at different temperature levels.

In the low-temperature range, the base developments do have a technical, but not economically satisfactory level. Thus, work shall continue on the development of low-cost systems. In addition, other efforts are needed in the medium temperature range (300 °C) and higher temperature range (900 °C).

The important possibilities for conserving energy by using passive elements have been discussed in the "Aachen Experimental Energy House" in connection with the use of active systems for solar energy use.

Since 1978 R&D activities have received essential support through the measures financed by the State, partly in cooperation with the states within the frame of the energy conservation program and the future investment program. About 100 solar or heat-pump systems were installed in Federal buildings, some of them have large area heat exchangers. In an accompanying program, the majority of these systems has been measured for their performance and their long-term behavior determined.

Heating Tap Water

The development of components and the investigation of solar systems was supported intensively in recent years through State funds with the result that today, methods for solar water heating are available on the market, whose use is promising even in Central Europe, e.g. for public and private outdoor swimming pools.

For research purposes in the FRG, a large, outdoor public swimming pool was equipped with a combined area-collector heat-pump heating system. This test field has 1,500 m² of surface area and continues to be one of the largest area-collector systems in the FRG. It has now been in operation for about 6 years.

In the future, projects will be pursued in this area, which collect statistical data on the long-term behavior of solar systems.

Heating Buildings

Active systems for heating buildings with collectors and heat stores were not able to penetrate the market due to high costs. Nonetheless, with existing, installed facilities, extensive experience has been gained which is important for further R&D.

Although there is little hope for rapid success in the area of the long-term store, it is still necessary to continue heat-storage research, since this component will play a significant role in the success or failure of active solar space-heating systems.

Heat-pump systems with area heat-exchangers have not found a broad market acceptance. The advantage of large-area heat-exchangers is that ambient heat can be taken by them--except in extreme weather conditions--at the time of heat demand, in a manner generally independent of direct solar radiation.

The emphasis of further development of active solar heating systems is on:

- highly efficient and low-cost collectors
- new storage techniques
- testing and checking methods on safety, reliability and ageing behavior
- simulation, control and regulation strategy
- increasing reliability over the long-term.

In contrast to this, passive utilization of solar energy for space heating uses collection, storage and distribution of heat through the structural components and through the architectural design of the building.

At present there is little experience available on the effectiveness of various concepts for passive solar energy under Central European Climatic Conditions. In individual publications, theoretical potentials have been determined, according to which between 20 and 60% of the heating energy needs can be saved. A determination and evaluation of results in this area could provide important results for future developments. In particular, the latitude effect of the demonstration projects initiated within the frame of the on-going program could be estimated.

The following factors have a quantitative influence on the passive utilization of solar energy:

- Building shell with geometry, alignment, material, insulation and distribution of transparent and non-transparent surfaces
- Building interior with organization, distribution by temperature zones
- Solar absorber surface area
- Parts of the main structure as heat store

-heat transport system

-control and measuring instruments with their reliable climate tolerances and heat regeneration, force-air ventilation and internal heat sources.

The influence of building geometry and alignment, of heat insulation and of the ratio between transparent and non-transparent outer surfaces and of any temporary heat preservation is being investigated in several on-going projects. A large savings in space-heating demands is expected from this.

Experiences gained in other climate zones and countries with passive systems show that heat storage and control of the heat flow are critical factors which frequently lead to overheating in summer using modern building designs. For this reason, projects should be promoted where active and passive components are integrated into a single concept.

Projects should be funded which already have close cooperation and joint planning by building contractors, architects, advising engineers and building physicists right from the first preplanning stage, since only under these circumstances is a complete utilization of the energy-saving potential to be anticipated.

Increased theoretical, and above all practical development work, should be performed in future in the area of:

- variable building shell which permits a reaction to the climate (shading against overheating, light control to improve energy use and temporary thermal insulation with the same building component)
- old facade improvement by addition of passive systems (trumpet-wall, thermosyphon, air collector, winter garden on balconies etc.)
- potentials for saving energy by buffer action and improving housing quality by indoor greenhouses (winter garden)
- optimization of storage action of building walls and additional stores, including latent stores at room temperature
- hybrid passive systems and their additional energy demand for heat transport
- special construction and storage engineering for energy-intensive buildings (e.g. greenhouses).

But above all, the architects, building engineers and climate technicians must have available useful tools for optimizing the heating energy needs of buildings with simulation programs for the passive systems. Optimization of these programs for German conditions is not yet underway.

Process Heat

With solar engineering, in principle high temperatures of several thousand degrees Celsius can be produced. In the FRG only the range up to about 200 °C comes into consideration due to the climatic conditions.

With regard to the application potential in sunny countries, even within the EEC, solar-generated process heat can become important for:

- treatment and desalination of brackish and sea water
- boiling, vaporizing and drying processes
- refrigeration of foods
- air conditioning.

For temperatures over 200 °C, concentrating collector systems are needed. They must track the sun automatically and concentrate the sunrays to the peak of a tower (solar-tower principle) or to a radiation receiver directly in front of the individual mirrors (solar-farm principle). The radiant energy is released there to a heat carrier (water vapor, air, thermal oil, sodium). For heat with a temperature level between 200 °C and 800 °C there are applications in many areas of process technology, including electricity generation.

Initial systems for practical system-investigations were planned and are in the implementation phase.

These R&D efforts are characterized in particular by the development of solar-related components, e.g. tracking equipment, geometry of the radiation receiver, reflectors and reflector structure, and by the manipulation of technical system interrelationships, including storage and different modes of operation.

4.3 Electricity from Solar Energy

Solar energy can be converted into electricity either via thermal processes or directly via photocells. Today, in the small power range and due to the successful completion of various projects, photovoltaic energy supply systems are lower in cost and easier to use than solar-thermal systems, due to their relatively simple, modular design and their lower maintenance needs.

An economical supply with electric current from photocells is already possible today for special purposes, even in Central Europe, provided small powers are needed in remote regions. This market can be increased significantly through the anticipated reduction in system costs.

An economical operation of solar-thermal power plants is not possible in the FRG due to existing climatic conditions and using present cost estimations. The R&D efforts are thus aimed primarily at facilities which can be used in regions with more, direct solar radiation for energy supply (current and process heat).

The economical use of solar power plants depends on many factors: The technical availability, the attainable efficiency, service life of components, the investment and operating costs, the mode of operation, the consumption profile, future oil prices and the foreign-exchange situation of the particular country. Experimentally confirmed findings on the technical availability and attainable efficiency of solar power plants are still insufficient.

Solar-thermal Conversion

Solar-thermal power plants to generate electricity are being studied in the FRG exclusively in cooperation with other nations or international organizations (EEC, OECD/IEA). A series of facilities in the range from 10 kW to 1 MW electric power output were erected. Different collector systems for different temperature ranges, heat-carrier media and thermodynamic cycles as well as the corresponding heat motors were used.

The emphasis was on the EURELIOS on Sicily and SSPS (Small Solar Power Systems) in Almeria, Spain. EURELIOS is a solar-tower plant (1 MW_e), which was erected and operated in cooperation with France, Italy and the EEC commission. The SSPS is actually two projects performed within the framework of the IEA: A 500 kW_e solar farm power plant.

The goal of long-term test programs is to propose, develop and test various concepts for solar power plants with their different key components and thermal cycle-concepts, but also to find realistic criteria for evaluating the operation in order to estimate future practical potentials. It is also investigated how the economy and efficiency can be improved by combination of solar-thermal electricity generation with step-wise waste-heat utilization or by switching to high power ranges (10-20 MW), higher temperatures and other heat-carrier media (technology program for gas-cooled solar turret power plant GAST: 800 °C, heat carrier medium, Air).

Photovoltaic Conversion

The direct conversion of solar energy into electric current with photocells needs no mechanically moving components. The reliability and service life of such a system depends on the properties of the used semiconductor and its protection against environmental factors.

Crystalline Silicon Solar Cells have proven themselves in space for more than a decade. Through the funding of the BMFT, the production costs for solar-cell generators has been reduced between 1978 and 1981 from 100 to 120 DM per Watt of peak power, to 20 to 30 DM. At this price level they have found economical use in special cases in terrestrial energy generation systems.

Decisive prerequisite for a broader terrestrial application is a further reduction in manufacturing costs, not only of the solar cell generators, but of all components of the photovoltaic system. Of course, the results of previous development efforts indicate that the production costs of the solar cell generators can be reduced significantly in coming years, but the other system components, like rectifier and a.c. converter, batteries for load equilizing and control features point to a far lower potential for cost reduction. These components will increasingly affect total system costs and be a limiting factor for the economical use of smaller and medium-power facilities. The development of modular components and systems which permit useage over a broad spectrum of potential applications without adaptation problems, will in future become more important, in addition to further development of solar-cell technology.

The results of previously completed projects indicate that the industrial production of photocells from mono- or poly-crystalline silicon can begin even during the term of this program. But considerable development effort is still needed for the production of mono- and polycrystalline silicon and for industrial trial production of solar generators from polycrystalline silicon cells.

The most important development goals are:

- cost reduction in the production of polycrystalline silicon and new production methods for mono-crystalline silicon which maintaining or increasing the efficiency of solar cells produced therefrom.
- low-cost production methods for solar cells with high reproducibility
- reliable encapsulation of generator modules to protect against environmental effects.

In addition, developments toward technical and economical optimizing of photovoltaic energy generation systems are being continued. Of primary interest here are low-loss energy-processing modules, suitable electrical energy stores and adapted consumer devices.

The FRG is conducting field tests with photovoltaic systems with third-world countries within the framework of bilateral agreements. For the operation of pumps, of water treatment systems and for a power supply to communications facilities and for other applications of low electricity consumption in remote areas, numerous facilities have been put into operation or are in preparation. Efforts are being made to continue these field-testing projects to gain information about the manifold demands on such systems and to improve the design criteria for photovoltaic generating systems.

Lower demand for expensive raw materials and less-intensive energy demand for process technologies offer important indications for a simple and low-cost production of thin-film solar cells in the future. However, extensive fundamental work is needed to understand the mode of operation of these cells and to develop industrial production methods.

Fundamental and process-oriented research on new materials for thin-film solar cells, especially of amorphous silicon, is an important emphasis of the work. One important goal is to increase the conversion efficiency for large-area cells.

4.4 Energy from biomass and Wastes

Besides the traditional utilization forms for agricultural and forestry products, there are also fundamental possibilities for using them to generate energy. These possibilities must take into account the requirements of rural and environmental protection and the general requirement for use of agricultural space for growing food.

The use of biomass as an energy carrier offers an advantage over most other renewable energy sources since either the biological starting material or the generated end product can be stored so that a consumption-oriented energy supply can be created in most cases without reserve systems or complicated large stores. In addition, new technologies are needed only to a limited extent: For waste combustion, alcohol fermentation, biogas generation, charcoal production and wood gasification and wood saccharification, methods are already known, which in many cases, will have to be adapted to present technical, economical and environmental-policy requirements.

In addition to the construction of new, decentral energy-supply systems, as a rule existing technical aggregates can continue to be used with energy carriers obtained from biomass, like e.g. diesel engines using wood-gas generators or plant-oil use; ethanol and methanol can be used with the Otto engine with minor adjustments.

An advantage of biomass use is that the production of systems for combustion, gasification or pyrolysis is more feasible in developing or emerging nations than the production of larger wind turbines, solar cells or thermal solar power plants. Thus, the foreign-exchange problems of the countries can be alleviated.

Basically, two types of biomass-energy use exist:

- the recovery and use of previously unused biomass potentials, especially of byproduct and wastes from agriculture and forestry, of the food industry, of industry and private households
- the specific production and processing of growing raw materials (primary agricultural and forestry products) for industrial-commercial purposes (alcohols, gases, starch, plant oils and fats).

For reasons of rational raw-materials use, the recovery of communal, industrial, agricultural and forestry wastes is particularly important.

In contrast to the byproduct and waste products, agricultural and forestry primary products will only be important in future--due to the quickly rising world population--in those countries having abundant agricultural production reserves compared to the population. In the FRG and most EEC countries, a specific culturing of energy plants can be considered if this is meaningful from an overall economic viewpoint, and when the requirements of domestic food production are not restricted and existing and future obligations of food exports and food aid are not infringed.

Brackish areas and polluted agricultural sections can be considered for growing energy plants; in these locations the growing of foods can be problematic due to the pollution of the soil.

The present state of technology is described as follows:

Facilities for burning wood chips can be considered matured today for the usual power classes. The use of high-energy wastes (agricultural,

industrial, e.g. from the food industry) is technically possible only in special cases, like e.g. straw burning in medium-size, automatically charged incinerators. Small systems would not have exhaust scrubbing for economic reasons and usually do not meet German emission standards.

Through the refinement of garbage-sorting techniques, in addition of existing incineration methods, it will be possible to separate out the combustible fractions and to process them into a storable and transportable fuel. The calorific value of this fuel substitute (BRAM) is on the same order as wood. The advantage over direct combustion lies in the potential for flexible use.

The contribution of waste recovery toward the energy supply is already notable in the FRG. In 1980, 30% of the occurring garbage was used in 42 garbage-incineration facilities; it had a heating value of 1.8 million tons of hard-coal units and generated electricity and heat.

Biogas engineering is a relatively recent development and has advanced rapidly in India and China. The fact that the energy use does not restrict a downstream use (e.g. as fertilizer) makes this method particularly attractive. Biogas systems have been developed primarily only for feces, although other starting materials with a high moisture content are suitable. In the FRG biogas engineering has been used on a large scale only for the stabilization of clarified sludge in municipal water-treatment plants. Recently, the use of disposal-gas has become economically interesting, but the energy yield is very low and only of local importance.

Thermo-chemical gas generation (gasification, pyrolysis) was widely used in the FRG during the 1930s and 1940s both for stationary systems and for vehicle drives. The simple wood-gas solid-bed generators developed at that time are again the pattern for the refinement of these systems.

Gas generation from garbage using low-temperature pyrolysis with rotating drums has advanced so far that its continued technical development appears promising.

Since these gases (biogas and wood gas) can be used easily in internal-combustion engines, they have a certain potential for generation of electricity and for stationary drives in remote regions.

In contrast to gas generation in small-power facilities, the liquifaction of biomass is presently being studied in large-scale facilities. Due to the large space requirement for production of biomass, a considerable expense is incurred for planting, harvest, transport and detoxification of wastes.

Due to the research deficits in these problem areas, at present trial and demonstration plants of different size are in the planning, construction or testing phase for the production of ethanol from sugar and starch-containing plants.

There are still no actual values gained from experience in the FRG on the generation of methanol from wood, straw and other raw materials in large-scale facilities. Nevertheless, this production line might be important for the future once large quantities of cellulose materials become available (primarily straw, residual and waste wood) and if there is no direct competition for the materials for producing food.

In the concluded energy-research program, primarily facilities were funded for the combustion and gas generation from biomass in order to improve the process technology and to have a more energy saving, economical and non-polluting technology. In addition, the demonstration of such plants was funded to promote their introduction to the market.

Future Research Emphasis

With this as background, the new projects have the following primary objectives:

- Reduction of environmental problems from the use of biomass and wastes, and optimal raw-material utilization
- Refinement of firing, gasification and pyrolysis systems for the various municipal, industrial and agrarian wastes
- Testing and adaptation of biogas systems for various wastes and system sizes
- Generation of liquid fuels
- Optimization of raw-material extraction, collection and transportation and storage, including development of suitable treatment methods
- Testing of generally energy-autarchic systems in agriculture
- Investigations on combined nutrient and energy-plant useage.

Parallel with the work on waste generation, investigations must be performed on the marketing of garbage fractions and technologies developed for waste avoidance.

4.5 Wind Energy

Wind, unlike solar energy, is not directly dependent on the time of day and season, or on latitude. In addition, it can be converted at high efficiency into mechanical or electrical energy.

The current technical status of wind converters is characterized by the attempt to move from the traditional multi-blade pump wheels to high-efficiency wind turbines--similar to the development of water wheels--to water-turbine designs.

Due to the special problems with regard to turbine and ventilator design (long rotor blades, instationary wind conditions), the technical mastery of the occurring loads is more difficult than originally considered, even for small facilities.

Previous project experiences confirm that the technical problems increase with the system size. Thus it is expected that initially, small systems (up to 50 kW) will predominate. An economical use (e.g. to supply heat to a small consumer) is only possible in windy regions (coastal) in the FRG at present. In developing countries however, even today wind energy systems can be used economically where a conventional energy supply is difficult and expensive for logistical reasons.

Within the frame of previous projects, the adaptation of small wind-energy systems to special consumers (electricity, heating, pumps) and the operating behavior have been investigated. Previous tests have shown that only a few types of wind energy systems can meet the demands. Thus the refinement of existing facilities to attain technically acceptable reliability is of primary interest.

The problems connected with the numerous potential applications (heating, generating electricity, heat-pump operation etc.) and the safety, legal and economic questions of wind systems must be investigated in future at favorable sites in cooperation with the communities and on the basis of demonstration facilities.

An increase in numbers and a measuring program accompanying a larger number of existing or new systems, including bilateral projects to collect operating experiences under different conditions, is considered to be a prerequisite for an economical breakthrough of these systems.

Due to the safety aspects and adaptation to the landscape, only a few building permits have been issued. As long as there are no recognized standards for important wind-energy components (DIN standards, VDI-specifications, accident-prevention regulations etc.), the approval and licensing situation with its esthetic considerations, will continue to be unclear.

For medium and large systems, in the past considerable progress has been made. Since these systems are connected with relatively high technical risk, even in other countries (USA, Sweden, Denmark) where they are under development, there is a continuing information exchange with the IEA within the framework of an agreement.

The potential uses of larger wind generating systems (WEA) were viewed formerly as mainly in the area of public electricity generation. Due to the fluctuating availability of the systems, they could not replace other generating facilities, rather they could only be used as a fuel-saver during windy times. For the FRG therefore, wind energy generation is not ranked very highly, since at the time of potential, broad market introduction, scarce energy carriers (petroleum, natural gas) might be used only a little to generate electricity and thus no notable substitution potential will exist.

But in countries where today and in the future oil and gas will continue to be used to generate electricity, wind-energy systems can be used as a fuel-saver to a significant extent in operation parallel with the conventional generator.

In the FRG there is an attractive area of employment for larger wind energy systems, especially in the supply of heat or a combined heat and electricity supply. This applies essentially for the supply to smaller communities or settlements, where the wind energy system can be set up in a windy area outside the community.

The previous developments (GROWIAN, 3 MW, MBB-monowing, 300 KW, Voith system, 200 KW) are generally independent of the employment concept. They must first demonstrate their technical reliability in the coming trial phase.

The work is concentrated on the following points:

- Completion and testing of the systems developed within the frame of the first energy research program (incl. the upwind power plant at Manzanares, Spain)
- Development, construction and testing of components and systems
- Problems of storage or feed into the mains
- Determination of environmental factors.

4.6 Geothermal Energy

The potential uses for geothermal energy are limited by economic and environmental problems. Sufficient temperature levels (ca. 200 °C) usually occur only at great depths (6000 m). Its extraction is presently uneconomical due to high drilling costs. One exception is the so-called geothermal anomalies, where high temperatures are encountered at low depths. In addition, the recovery of geothermal energy is only possible when hot water or steam is available as a store and transport medium and the subsoil is of sufficient permeability. Such favorable geological conditions are of locally limited size and occur singly.

At present, geothermal energy is used to generate electricity and heat in Iceland, Italy, Japan, El Salvador, California (USA), New Zealand, Mexico and on the Philippines.

In the FRG the temperatures at economical depths are not high enough to generate electricity. The geothermal heat will probably only be useful domestically for heating purposes.

Corresponding demonstration projects are underway in Bremgarten by Freiburg and in Saulgau. Other projects with different, geological problems are planned.

Another possibility for using geothermal heat is the so-called hot-dry-rock-method. Here, the hot rock in the subsoil is broken up by blasting or injection of water. Water is fed into the resulting fissures, becomes heated and is removed through a second hole.

The FRG is participating in a hot-dry-rock project in the USA to develop this technology.

The R&D on geothermal energy also is being promoted by a sub-program of the Energy Research and Demonstration program of the EEC.

In order to intensify geothermal knowledge in the FRG and to open up new potentials for its use, the

- collection of geothermal data
- geothermal prospecting and exploration
- testing of new prospecting methods

is needed.

5. Nuclear Fuel-Cycle and Reactor Safety Research for Light-Water Reactors

Within the framework of the nuclear program, many different concepts for nuclear reactors were investigated and the particular developments have been carried forward to different degrees. The light water and (under certain conditions) the heavy-water reactors have turned out to be technically reliable and above all, economically competitive. World-wide light-water reactors are predominately used (as boiling-water and pressurized-water reactors), and the number of pressurized-water reactors predominates.

Funding of commercial light-water reactor technology reached its concluding phase with the operation of the Gundremmingen (250 MW_e, 1966), Lingen (252 MW_e, 1968) and Obrigheim (345 MW_e, 1968) demonstration plants. The technical-economic risk of these facilities was covered by the state through a risk-participation agreement for the operating phase. The investments were not promoted with R&D funds. The overall successful operation of these facilities--Obrigheim is still in operation--was the prerequisite for further expansion of commercial nuclear energy utilization in the FRG.

The development of the heavy-water reactor was technically successful. The MZFR (multipurpose research reactor) of 60 MW_e has been in operation since 1965. The availability of this reactor^e is internationally acclaimed. The export successes for this system are based primarily on its technical reliability. In spite of certain economical disadvantages, they can be of interest primarily in countries having their own uranium deposits, but not the technology of uranium enrichment.

State funding of further development work is concentrated on technologies serving for a safe use of light-water reactors. This applies especially to techniques for closing the fuel-cycle and for increasing the safety of nuclear facilities and special aspects of the power supply.

In the area of decontamination, the State has taken over direct responsibility for the safe disposal of radioactive wastes in accord with the Atomic Energy Law. The methods developed to technical maturity still partly need a large-scale demonstration and the accompanying, optimizing development during the transition to the market phase. The sphere of reprocessing of nuclear fuels, which is

the responsibility of industry, still requires some additional, accompanying R&D funding. At the same time, the Federal government is instituting investigations on the feasibility and safety evaluation of direct, final disposal of spent fuel elements.

To secure the nuclear fuel production, the development of uranium enrichment using the gas centrifuge method is being continued on the basis of the agreement concluded in 1970.

Overall, the fuel cycle is concerned with the safety of the particular facilities and with **relieving our dependence** on foreign energy imports. There is one other aspect: To support the availability of fuel for enhancing our export position with respect to nuclear power plants without awakening a desire on the part of countries with a small nuclear energy program, for their own nuclear fuel reprocessing facilities. Concepts and techniques for controlling fission products are of particular importance for uranium enrichment and reprocessing.

State funding is to be continued--even at the attained high standard of reactor safety and radiation prevention--in order to improve the protection of the population and of operating and service personnel in nuclear facilities, under consideration of increasing use of nuclear energy and to keep the residual risk small compared to other accidents and natural hazards. The medium need for state funding of reactor safety research will drop during the 1980s, however. This is made possible in part by the successes of preceeding funding. In addition, with increasing commercial use of light-water reactors, the manufacturer and operator will increasingly undertake their own efforts toward safety refinements and to increase operating reliability.

Previous work on reactor safety of light-water reactor systems confirms that the installed safety redundancy is as a rule more than satisfactory. Although efforts to improve the safety of nuclear power plants will have to continue, e.g. through more detailed analyses of complex accident sequences with quantification of risks to identify potential, remaining relative weakpoints, the need for State funding of reactor safety research on light-water reactor systems will decrease over the medium term.

5.1 Uranium Supply and Conversion

The uranium supply and the process steps of conversion, uranium enrichment and fuel element production all belong to the fuel cycle. The emphasis of funding is on uranium supply and enrichment. In 1980 the demand for natural uranium amounted to ca. 1,500 tons.

Uranium Supply

The FRG must rely on foreign deliveries for its nuclear fuel. The measures supported since 1956 by the BMFT to secure an uninterrupted and reliable supply of nuclear fuel to German nuclear reactors are aimed at a diversification of the sources of supply, at the establishment

of stockpiles, at the development of new sources of supply and at the development of technologies of uranium extraction.

At the end of the 1960s, German firms with Federal support, began to participate in the exploration of foreign uranium deposits and to win agreements for participation in deposits and mines (since 1980 such measures have been supported only by the BMWi under the same conditions as commercial exploration projects for other raw materials). Through the participation in deposits and the conclusion of long-term delivery agreements, the uranium supply to German nuclear power plants has been about 80% secured to the year 1990. However, after 1990, the fraction of uranium deliveries now secured through mining participations, will drop off.

From 1956 to 1980, Federal funds in the amount of over 338 million DM have been appropriated for promoting projects to search for and extract uranium (BMFT and after 1978, the BMWi)

In the 1970s, the Federal uranium reserve was set at around 438 tons of enriched uranium after a foreign-exchange agreement with the USA; this amounts to about 46 million tons of hard-coal units. It would suffice to meet the refueling needs of present reactors for at least 1½ years.

In deposits of the FRG today, a secured uranium reserve of at least 5,000 tons of uranium and additional, estimated reserves of 8,500 tons is estimated; this must also be viewed under the aspect of supply assurance.

To develop new sources of supply, since 1974 fundamental R&D work has been funded to extract uranium by using bacterial leaching and in-situ leaching, and from sea water (practically inexhaustible supplies of 4.3 billion tons). On a pilot scale, an effective method of bacterial leaching has been developed. Results of the in-situ leaching were already applied to domestic and foreign deposits. Protection of the miners against radon gas was expanded and the establishment of spoil banks was made more environmentally sound. Information was obtained on uranium extraction from sea water, especially with regard to suitable adsorbers and the needed marine technology which makes a medium-term completion of the project seem feasible. The concept of floating systems for use on the open sea is taken as a basis.

Even though at present, uranium is available in sufficient quantity and at favorable prices on the world market, according to investigations of OECD/NEA and the IAEA, between 1990 and 2000 a situation will develop where the demand will have to be met from production of uranium from mines having higher extraction costs.

Due to increases in 1981, the OECD set the proven uranium reserves of the Western world at 2.3 million tons. The additional assumed uranium reserves are estimated at 2.7 million tons. In 1980, nearly 44,000 tons of uranium was produced. By the turn of the century an annual demand of ca. 100,000 tons is expected. These

figures illustrate that the known uranium reserves, compared with other primary energy carriers, will be exhausted in relatively short times. For long-term assurance of the uranium supply, additional R&D measures are needed. They must be aimed in particular at improving search methods for uranium supplies, at low-cost production of natural uranium and at developing new sources of supply.

The BMFT-funded R&D work will in future concentrate in particular on problems of economic geology, on improving mining search, extraction and processing methods, on prevention of pollution and on new mining methods, like uranium from sea water, phosphoric acid and uranium-containing low-grade ores. The work will be performed in cooperation with the Federal Agency for Geosciences and Raw Materials (BGR), State Geological Offices, Large Research facilities and industry.

The domestic R&D work will be supplemented by an R&D program of the EEC in the area of uranium exploration and extraction.

The EEC has made funds available since 1976 for exploration projects in EEC countries according to article 70 of the Euratom agreement. These efforts have considerably expanded our knowledge of member countries' uranium potentials.

In addition, committees of the OECD/NEA and of the IAEA are concerned world-wide with questions of uranium reserves and supplies. They are promoting an improvement of methods of prospecting and extraction, especially through information exchange. One project performed by the NEA/IAEO to determine the world uranium potential is called the International Uranium Resources Evaluation Project (IUREP) and is also funded by the BMFT.

Conversion

The conversion of the natural uranium delivered by the producer (U_3O_8) into uranium hexafluoride (UF_6) as input material for the enrichment plant, has previously been performed abroad. In order to attain a certain independence from this part of the fuel cycle as well, we must investigate whether and under what conditions, such a conversion plant can be licensed in the FRG. It is particularly important here that the currently operating, foreign plants produce a considerable quantity of radioactive nitrate and fluoride-containing wastes. Thus, since 1980 development work by industry has been funded for a low-waste conversion method while retaining the basic technology proven abroad.

5.2 Uranium Enrichment

The Federal government supports measures in the area of uranium enrichment to assure the supply of enriched uranium to German reactors. The gas-centrifuge method stands in the foreground. In addition, the separating-nozzle method and new enrichment methods are being funded. The need for uranium separation work ran to about 1,100 t UTA in 1980.

Gas-Centrifuge Method

The development and use of the gas centrifuge method has been in progress since 1970, jointly with Great Britain and the Netherlands, within the frame of the agreement of Almelo of 4 March 1970. The governments of the 3 countries are obligated, according to this agreement, to fund the set-up of joint industrial companies, the construction and operation of enrichment facilities and an integrated R&D program. The goal of the funding is to make the industrial concerns competitive on a commercial footing compared to other producers of enriched uranium.

The enrichment organization established for this work, comprises URENCO Ltd in Marlow (Great Britain) as the central marketing agency, CENTEC GmbH in Bensberg (FRG) as central agency for coordination of R&D programs, management of protected rights and technical know-how, and the three industrial concerns: URENCO UK in Capenhurst, URENCO Netherlands in Almelo and URENCO Germany in Gronau.

Initially, pilot plants were set up in Capenhurst and Almelo with a total 60 t UTA/year (tons of uranium separation work per year), and they began operation in 1973 to 1975. The so-called 2000 t UTA/year program of URENCO is underway; it had been planned for completion by 1982 based on the delivery agreements concluded in the mid-70s. Due to the lagging demand, the expansion has been pushed back to the second half of the 1980s.

Even though the further expansion program of URENCO will be determined fundamentally by the developments of nuclear energy in Great Britain and the FRG, URENCO has since become a partner having increasing influence on the world enrichment market. The technological advantage of demand-oriented expansion and low energy costs of the gas-centrifuge method are increasingly important.

Within the frame of the 2000 t UTA/year program, in 1977 demonstration facilities were taken into operation at the Almelo and Capenhurst sites; in 1980 they reached their rated capacity of 200 tons/year each.

In Almelo and in Capenhurst in 1979, the construction began on an additional capacity of 400 tons/year or 230 tons/year respectively.

As a site for the uranium enrichment facility of URENCO, Germany oHG, after detailed study the city of Gronau in West Münsterland in North-Rhine Westfalia was selected. The initial partial approval (TG) for the first construction segment of 400 tons/year of a 1,000 tons/year plant was issued at the end of 1981.

Although the technical goals of development of centrifuges were fully attained and the use of the gas centrifuge method has run quite successfully to date, the goal of commercial competitiveness on the world market has not been fully attained due to a changed market situation.

The additional R&D work is concentrated on an advanced centrifuge line with a different rotor material which permits a significant increase in separating power of the individual centrifuges and thus a corresponding reduction in investment costs. The development of these centrifuges proceeded so successfully that presumably by 1986 systems can be equipped with the new device.

The German partner in the trilateral industrial cooperation is URANIT, which is also the German partner in the URENCO enrichment organization.

Separating Nozzle Method

The principle of the separating nozzle method was worked out by the KfK. An initial technical application takes place on the basis of the German-Brazilian cooperative agreement. The Brazilian company NUCLEBRAS, the German Co. STEAG and INTERATOM and the KfK are all participating. An inlet cascade is under construction in Brazil. An expansion to a demonstration plant is planned in two stages (to 100 or 300 tons/year). In addition, within the frame of a technology program, the construction of a commercial plant is in preparation. The refinement of the method is being performed within the frame of an R&D program coordinated between the participants and implemented by the KfK and NUCLEBRAS.

New Enrichment Methods

Of the known, new methods for uranium enrichment, the laser method is the most promising. Orientation tests have led to concrete goals in an R&D program. In the 4-year program begun in 1980 the concept of a laboratory facility to perform separation tests was worked out. Participants are URANIT, the Max-Planck Society, the Battelle Institute and the Rheinisch-Westfälische Technical University in Aachen.

The investigation on plasma centrifuging was terminated in mid-1979, after the attained results were judged negatively.

5.3 Fuel-Element Production

The production of uranium-oxide fuel elements for light-water reactors has since reached technical maturity. In order to make better use of the nuclear fuel, an improvement of reliability and safety behavior of the clad tubes is needed. Additional State funding is needed for the pertinent projects.

The development of fuel-element technology for breeder reactors is a part of the overall concept for promoting this advanced reactor system.

The same applies in principle for the development of fuel-element technology for the HTR. Development work is needed to produce fuel elements with low-enriched uranium and to increase their operating temperature and burn-off rate.

In order to reduce the danger of nuclear weapons proliferation, the international evaluation of the nuclear fuel cycle (INFCE) recommended the restriction of the use of highly enriched uranium in research and material-test reactors to the minimum necessary. As in other countries, R&D work has commenced by Germany. New fuel-elements are being developed for instance, which have no effect, or at least no negative effect, on the experimental properties of research and material-test reactors even at their low level of enrichment. The work is prescribed by a 5-year program begun in 1980 with the cooperation of the American Argonne National Laboratory (ANL). Large German research centers and industrial concerns are participating in this. Enrichments below 20% are the goal.

5.4 Fuel Reprocessing

Introductory Comments

The reprocessing concept of the Federal government has changed in the course of the first energy research program. Since 1974 the integrated reprocessing center idea has been followed. Its realization has been planned since 1977 in Gorleben. In the meantime, the State government of Lower Saxony has expressed its opinion on the Gorleben nuclear reprocessing center in a decree of 16 May 1979. It confirms that a nuclear reprocessing center of satisfactory safety can in principle be erected on the site, but recommends to the Federal government that the project of reprocessing in Gorleben be dropped; the political prerequisites are said not to exist. With their decision on decontamination of nuclear power plants of 28 Sept. 1979, the government heads of the states and country have drawn their conclusions from the decision of the State government of lower Saxony: The integrated reprocessing concept of the Federal government is confirmed and additional steps for its completion have been specified. Within the frame of this concept, it is possible to separate spatially, individual reprocessing facilities, like e.g. interim storage, reprocessing, refabrication and waste treatment and final disposal. The government heads agreed that a reprocessing facility should be erected as soon as possible, under consideration of all pertinent viewpoints. In addition, it was specified that other reprocessing techniques be investigated, like e.g. direct final disposal of burned out fuel rods without reprocessing, for their feasibility and safety in order that a final decision can be made about whether decisive safety advantages could result from them for the 1980s.

The recommendations of the Enquete Commission on future nuclear energy policy of the 8th German legislative session confirm the decision of the government heads. The decision on the detoxification route to be taken is proposed in these recommendations to be taken no earlier than 1990. It was also proposed that the feasibility of the needed reprocessing steps be shown by demonstration plants for both reprocessing methods, provided this is needed for technical reasons.

In accord with the division of tasks between State and industry, the construction and operation of reprocessing plants including treatment of radioactive wastes and return of recoverable nuclear fuels, uranium and plutonium, is the responsibility of industry.

The government has been working since 1976 to establish the facilities prescribed in the atomic energy law for the safe storage of radioactive wastes. The Federal Physical-Technical Agency (PTB) is responsible for this. The costs connected with the erection and operation of the final storage site are to be fully borne by the generators of the wastes. The PTB is supported in the implementation of its tasks by the German Union for Building and Operating Disposal Sites (DBE) and the Federal Agency for Geosciences and Raw Materials (BGR).

In accord with their legal obligations and particular interest, the Federal government will participate in technology refinement in the area of reprocessing through:

- refinement, testing and implementation of safe techniques for the assurance and end-storage of radioactive wastes
- safety refinement of reprocessing (basis: R&D catalog of reactor safety and the Radiation Prevention Commission and its continuance) especially the refinement of components and methods having a high safety potential
- investigations on the risk-factor of reprocessing facilities in the fuel cycle
- investigations on preparation of the decision on whether definite safety advantages could result from the final storage of spent fuel elements without reprocessing.

For the handling of these tasks, the Federal government will also make available the potential of the nuclear research centers. In addition to safety questions, we are also dealing with the development of new or futuristic technological steps. The Federal government likewise promotes development work by industry in the above areas. Scientific endeavors on the chemical, process-technology and technological principles of the reprocessing sector are also underway at the universities. Through the promotion of an intensive international cooperation within the frame of the EEC, the international organizations NEA and IAEA, and bilateral cooperation with various countries, it is possible to avoid wrong developments, to reduce costs in certain investigations and to support our own results and finding through information exchange, and thus to reinforce the technical position of the FRG in this special area of technology.

Transport and Interim Storage

According to the decree of the government head of 28 Sept. 1979, the spent fuel rods are to be interim-stored without reprocessing until a reprocessing facility becomes operational, or until a facility for conditioning for final storage comes onstream. This interim storage can be both in the nuclear power plants or in external interim stores.

Approval-steps for compact stores in nuclear power plants and for external interim stores in Ahaus and Gorleben with capacities of 1,500 tons each are underway. Industry is planning to use special

transport containers at the latter plant. Construction work on the Gorleben interim-store began at the beginning of 1982. The participation of the Federal government in research projects for interim storage is aimed only at investigations containing safety questions of radiation and environmental protection.

Reprocessing

The reprocessing of spent fuel rods has a key position for an intensive and progressive nuclear energy program: Fresh (uranium) and breeder (plutonium) nuclear fuels are regenerated for future use in new fuel rods; the radioactive fission products are separated and can be processed into safely-storable waste.

The reprocessing facility in Karlsruhe (WAK) erected and operated with Federal funds, and the international Eurochemic facility in Mol (with German participation) have provided in recent years, important operating experiences in the reprocessing of fuel rods from modern LWRs. The experiences gained in the USA, France and Great Britain were also confirmed.

Additional R&D work is aimed at:

- refinement and optimizing of components and process steps
- improvement of in-line instrumentation and analysis
- avoidance of waste quantities (e.g. through electrolytic steps)
- refinement and prototype testing of facilities for retention or burn-off of radioactive isotopes (especially iodine, krypton and tritium)
- investigation of accident sequences and effects (e.g. fire, criticality, leakage, filter rupture)
- adaptation of the PUREX process for the reprocessing of highly spent fuels and fuel rods of the fast breeder
- remote-operated repair and maintenance
- measuring instruments for fission product flux control.

The German Union for Reprocessing of nuclear fuels (DWK) placed an application in February 1980 with the Hessian Minister for Economics and Technology for the erection of a plant for reprocessing of nuclear fuels. In Feb. 1982 a regional planning study began in Bavaria for a reprocessing plant. Parallel with this, discussions began in Rheinland-Pfalz and other states on the erection of a reprocessing facility.

If the approval procedure proceeds without delays, operation of a plant is expected for the first half of the 1990s.

To manage the tasks of the state as per the division of labor with industry, the "Project on Reprocessing and Waste Treatment (PWA)" was founded at the Karlsruhe Nuclear Research Center (KfK) in 1974. In close cooperation with industry, this project will handle R&D work whose results will flow into the construction and operation of the large-scale facility. In 1979 a cooperative agreement was concluded between the DWK and the KfK which also regulates the financial side of the use of KfK know-how.

In the area of reprocessing there is close European cooperation via United Reprocessors GmbH (URG) with the participation of the French CEA, the British BNFL and the German DWK. The URG was formed in 1971 as a reaction to the overcapacities expected at that time, in the area of reprocessing in Europe. Today, its main task consists in promoting information exchange between the three partners and in particular, in providing assistance in case of capacity bottlenecks in member countries. As the first large facility, the French reprocessing center in Cap de La Hague will be available. The retrofitted English facility in Windscale has been repaired since an accident in 1973, for the reprocessing of LWR fuels. Since the reprocessing of Magnox-fuel rods is pressing, due to corrosion reasons, there has been no other reprocessing of LWR fuels there.

The R&D work on HTR reprocessing is concentrated at present, on investigations on the initial stage of a pilot reprocessing plant at the KFA (JUPITER). An intensification of efforts on reprocessing of SBR-fuel elements is intended which can build on previous experiences with LWR-reprocessing.

Waste Treatment

The treatment of radioactive wastes before their final storage pertains to radioactive wastes of all types. The goal of this treatment is to convert the wastes into solidified products which retain the necessary chemical and physical stability over very long periods of time under the conditions of final storage.

Liquid wastes also occur in the reprocessing of irradiated nuclear fuels. For the low and medium-active portions of this waste there already exist long-tested and proven concepts for solidification, e.g. solidification with concrete or bitumen (asphalt). The R&D work in this area has the primary goal of reducing the amount of waste products and to improve the chemical-physical stability of the final-stored products. In addition, methods are being studied for processing of waste mixtures, especially of medium-activity waste. The main efforts are directed toward the characterization of waste products, especially under accident conditions, and of quality assurance in the production of products fit for final storage.

For the solid wastes from the reprocessing facility, like e.g. for the fuel cladding, the methods of decontamination and compaction have matured in the meantime. For gaseous wastes, suitable methods of fixing are in testing--these methods must remain stable over a long time period. For the high-activity wastes, the concept of embedding in glassy substances is being examined. In France, this method has been demonstrated since 1978 in hot operation on an industrial scale. Domestically, in coming years the laboratory results and technological findings will be transferred to demonstration units. The construction of a sintering facility with German technology was begun by Eurochemic in Mol. This facility should go into operation in 1984/85. As end products, this sintering (vitrification) facility will output borosilicate glass blocks and borosilicate glass spheres embedded in metal (VITROMET); the facility is equipped with a ceramic fusion furnace.

Fuel Recycling

Spent fuel elements from light-water reactors still contain ca. 0.8% unused fuel (uranium 235) and ca. 0.9% breeder plutonium, of which ca. 70% is fissionable.

These fuels are available after reprocessing of the fuel rods, for renewed use in nuclear power plants, i.e. either in breeders or in light-water reactors, and they form a significant potential for conserving natural uranium.

The most effective use of plutonium is certainly in breeder reactors. For the long term, basic independence from natural uranium can be achieved in this manner. But the recycling of reprocessing products uranium and plutonium into thermal nuclear power plants improves the fuel economy. For example, the savings in natural uranium for the thermal recycling of plutonium is ca. 20% for the present light-water reactor strategy. If the unused, fissionable uranium is also returned to light-water reactors, there results an additional savings of natural uranium of 15-20%, using today's strategy. The full thermal closure of the fuel cycle is thus possible for plutonium. Thus it is possible that only small quantities of plutonium will get into the final store and this results in considerable ecological advantages.

The technology for the production of plutonium fuel for thermal reactors and breeder reactors (mixed oxide technology) is far advanced in the FRG. The FRG can be considered the world leader in LWR fuel production and recycling. Especially important successes of R&D from the past are the production of a mixed oxide fuel completely soluble in nitric acid by Alkem Co. and the solving of important design questions for mixed oxide fuel elements in LWRs up to a power class of 300 MW. By the mid-1980s, these technologies will progress so that their use will be possible in standard power plants of the 1300 MW-class in order to permit a profitable use of the plutonium from reprocessing.

In order to achieve this, it is necessary to continue the R&D program on plutonium recycling into thermal reactors. The most important goals are:

- continue development and qualification of the highly soluble mixed oxide fuel
- optimize plutonium use in the light water reactor
- implementation of multiple recycling of uranium and plutonium
- complete the use of plutonium in light-water reactors up to the 1300 MW_e power class.

An urgent goal of these development efforts is to answer the questions connected with the recycling, i.e. mainly the radiological exposure of man and environment in the fuel cycle is to be kept low, even for plutonium recycling, and the plutonium content in the production wastes are to be further reduced.

The implementation of these tasks is a joint technical and financial effort of the EVU, reactor and fuel element producers. The BMFT supports the necessary work with the goal of reaching independent continuation of these efforts by business after 1985.

Final Storage

The final storage of radioactive wastes must be performed so that danger to the biosphere is prevented over a sufficient time period. In the FRG the disposal of wastes in deep, geological formations having no link with the biosphere, is viewed to be the best solution.

In the international technical world, salt formations are considered to be particularly suitable, due to their geological and physical properties, for the final-storage of radioactive wastes. In North Germany there are favorable geological conditions for this storage.

Within the frame of this salt concept, at present research work is underway on the Asse and Gorleben projects. In the former salt mine at ASSE II, an extensive research and test program on final storage has been in operation by the GSF since 1967. It is important here to refine the technology of final storage in salt in the coming years, especially to have a demonstration of storage of highly active and medium activity wastes in drill holes and subsidence. In addition, special geological and rock-mechanical questions of the stability of a storage mine and temperature effects of the addition of heat-generating wastes, will be investigated. Suitability studies on the salt stock in Gorleben where four shafts have been sunk, and its environ will be investigated with more than three hundred hydro-geological exploration holes. There have been no results obtained which refute the suitability of a salt stock for the final storage of radioactive wastes. Final results will be obtained in coming years by means of shaft drilling and mining of the salt stock.

Besides salt formations, other geological formations are being investigated for the final storage of radioactive wastes. For example, the former iron ore mine at Konrad by Salzgitter is being checked for its suitability for the final storage of low-activity wastes and wastes from the shut-down of nuclear facilities. The study program was begun in 1976 and includes siting, geoscientific, mining and nuclear-technological investigations. Results obtained to date are positive; a nuclear licensing application will be filed and the procedure begun by the middle of 1982.

In addition to the Konrad mine, other solid rock formations are being investigated for their suitability as final stores. Under conditions prevailing in the FRG, granite rock formations seem the most suitable.

In addition, with regard to a secure detoxification, research work is being performed to remove occurring tritium waste water. The forcing of tritium waste water into a suitable geological formation is receiving the major interest here.

All R&D development work in the area of final storage is being performed in close international cooperation and agreement, e.g. within the framework of the EEC, OECD/NEA, IAEA or bilateral agreements with other countries (e.g. USA). Through the close international cooperation it is assured that the final-storage concepts in the different countries will satisfy similar safety requirements. In addition, knowledge on the final storage of radioactive wastes is being worked out in various final-storage committees. The program of the EEC in the area of waste treatment and final disposal is particularly important in this regard.

For a safety evaluation of the integrated decontamination concept, the project "Safety studies on Detoxification (PSE)" should provide some help. The goal is to prepare information on the risk contribution of reprocessing plants. The project is organized into two sub-projects, namely

- safety analysis of the above-ground facilities of reprocessing (e.g. reprocessing plant)
- safety analysis of the final geological store for radioactive wastes (long-term safety, migration of radionuclides).

The requirements of the government for plant-related R&D on final disposal are being given to the producers of radioactive wastes. The preliminary services regulation as per Art. 21b Nuclear Energy Law makes it possible to call in the waste producers at this stage for the financing of these expenditures.

5.5 Other Reprocessing Techniques

The investigations on neutralization without reprocessing, i.e. for direct final storage of spent fuel elements, refer back to the decree of the head of government dated 9/28/79. They are being performed within the framework of the R&D project "Other Reprocessing Techniques." The goal is to weigh and evaluate the safety aspects of direct, final storage of spent fuel elements, compared to their handling by reprocessing, and to provide an analysis of technical safety. Initially, the emphasis will be on "Conditioning and packing" and "Final Disposal." By mid-1982 a concept selection, e.g. between packing the entire fuel element, packing individual fuel rods, packing after cutting open the fuel rods, and packing after degassing the fuel rods, will be made. After this will come a detailed discussion of one or more concepts.

In working on the subject of "Final Disposal", the efforts made on the handling of conditioned, high-activity wastes can be used in part. This applies both for final disposal in drilled shafts inside a mine and also to the radiological and chemical interaction between final-disposal cask and the surrounding geological medium. In addition, special questions should be investigated which, under some circumstances, can cause a much different structure of the disposal site due to the large weights and dimensions of the casks.

This work is being supplemented by various experimental studies. Finally, system and comparison investigations will have to be performed on the basis of the individual results obtained. The investigations should be performed quickly so that a final decision can be made on whether any important safety advantages may arise from a different neutralization technique.

5.6 Removal of Nuclear Facilities

In coming years techniques for the removal of nuclear facilities will have to be developed and their use demonstrated in the removal of the Niederaichbach nuclear power plant. These development tasks are performed in part within the frame of a program of the EEC. Important information for the removal of nuclear facilities will also be obtained in the extensive program of Eurochemic (also funded by Germany). In this case, the Eurochemic reprocessing plants are being fully decontaminated and some sections dismantled. The cleaning of the plant has already progressed so far that in the meantime, all units can now be entered again. A proof of the safe removal of a reprocessing plant is being given here through an international project.

5.7 Control of Fissionable Material Flux and Protection Against Fissionable Material

In the area of peaceful use of nuclear energy and non-proliferation of nuclear weapons, the FRG has obligations within a network of public agreements like the agreement on founding the European Atomic Energy Union (EURATOM agreement), the statute of the international Atomic Energy Organization (IAEO) and the agreement on nuclear non-proliferation (NV-agreement).

The objective of these agreements and their controls is to prevent a diversion or misuse of fissionable material for non-peaceful purposes. In the FRG these controls are performed by the Commission of the EEC and are verified by the IAEO.

One important result of the international evaluation of nuclear fuel cycles (which was concluded in 1980) was that the spread of nuclear weapons is mainly a political problem and cannot be solved by technical means alone; but that together with international controls and institutional measures, the risk of proliferation can be minimized.

While perceiving its international obligations and for a constructive support of the work of the IAEO and EURATOM, the Federal government has actively contributed to the development of monitoring concepts and control techniques for the control of fissionable materials. These controls must be effective and reliable, but should not result in any international competitive disadvantages. In order to retain a general confidence and to improve international acceptance of the peaceful use of nuclear energy, the effectiveness of the safety measures must be carefully weighed against the fundamental requirement of not interfering unduly in the operation of nuclear energy facilities.

Besides the refinement and improvement of methods already in use, new monitoring concepts and techniques must be developed in the program term, and facilities of the fuel cycle, like enrichment and reprocessing must receive particular emphasis.

Examples for this are:

- improvement in material balancing techniques
- development and testing of containment and monitoring methods
- greater attention to the control necessities right in the plant design phase
- refinement of monitoring techniques in order to have an optimum utilization of available instruments (reliable, low-maintenance seals, cameras etc.)
- improvement of ADP and evaluation capacity of the monitoring organization.

In addition, there is fundamental research on the refinement of technical-scientific principles for the international monitoring of nuclear material under special consideration of political and economical boundary conditions.

Belonging to the work program are:

- the development and evaluation of monitoring and safety systems
- the analysis of secondary development lines, weak-points and of system design
- development of evaluation and valuation methods.

These efforts are also the scientific-technical basis for making decisions and valuation of international safety measures. They are being performed at the nuclear research center, Karlsruhe, the nuclear research facility at Jülich and by industry. A large part of this work is also the subject of the IAEA support program and is integrated into the ESARDA (European Safeguards Research and Development Association) R&D program. In addition, joint work is underway with the Joint Research Center (GFS), Ispra and the Department of Energy (DOE) in the USA.

Besides the control of fissionable material on its way through the nuclear facilities--which should permit an early detection of any diversion of material--in recent years an expanded protective system for fissionable material to safeguard it from the danger of a worldwide increasing number of terrorist and sabotage acts, has been put in place. It is an urgent priority to refine modern, useful protective systems which encompass the entire fuel cycle and to include structural, electronic and organizational measures. These efforts are simplified by the spatial integration of nuclear facilities, e.g. for the fuel cycle.

5.8 Nuclear Safety and Radiation-Protection Research

The Atomic Energy Law obligates the purchaser to take care that the needed precautions be taken against injury through the peaceful use of nuclear energy. They must also work toward keeping the

radiation exposure of personnel and population nearby, within the established limits or lower, under consideration of the circumstances of the particular use.

5.8.1 Primary Objectives

State funding of R&D on nuclear safety has tangibly contributed to a better understanding of the hazards connected with the use of nuclear energy, to recognizing relative weak points in the plants, and proceeding from this, to a refinement of the safety features.

Prevention of injury necessitates measures on nuclear power plants to protect against extremely unlikely accidents. An on-going check of the effectiveness of these measures must be a responsibility of safety research, since one can hardly rely on experiences of injuries in the past. An intensification of our understanding of the sequence of accidents and disruptions, and of the effect of protective and safety measures, continues to require a considerable effort in safety research.

In other Western, industrialized countries as well, especially USA, Japan and France, great efforts are still being made to improve the safety of nuclear facilities within the framework of extensive State-funded reactor safety research programs.

In spite of the attained--and internationally recognized--high level of safety of nuclear facilities in the FRG, there may be no stoppage in our improvement in safety engineering, in order that the hazard can be kept at its present level even with an increasing use of nuclear energy.

In the start-up phase of nuclear energy development in the FRG, these safety investigations were performed in the framework of development of prototype facilities. With the transition from prototypes to commercial plants at the end of the 1960s, the requirement for safety was defined as an independent task not reliant on prototypes with respect to the light-water reactors.

However, the investigations of safety of advanced reactor systems like the sodium-cooled fast breeder and high-temperature reactors, have been performed primarily within the frame of as yet incomplete prototype developments. The handling of safety questions pertinent to the reprocessing cycle and in connection with the shut-down and removal of nuclear facilities continues to be an important part of this development project.

The task of radiation-protection research is to expand our knowledge of the behavior of radionuclides in the environment and in organisms, and of the detection and action of small radiation doses. These efforts are important not only for the continued development of radiation protection measures and law, but also for a precise statement of risks which are in the center of public debate about the peaceful use of nuclear energy.

The projects of nuclear safety and radiation protection are being performed in the large research centers at KFK, KFA, GSF, GKSS, HMI, GFS (Ispra), the GRS, the BAM, the universities and industrial concerns.

5.8.2 Important Results of the Safety Research

Within the frame of the previous sub-program "Research on the Safety of Light Water Reactors" a large number of projects on important questions of safety has been completed or generally ended. For example, the investigations on the LOCA caused by large pipe ruptures have expired. Furthermore, in this regard the experimental investigations of the hot-steam reactor (HDR) should be completed; these efforts were initiated within the frame of the project "Containment in a LOCA" to verify the validity of extensive model testing on containment stress after a loss of coolant accident.

In the projects "Component safety", "Quality control" and "Containment failure", R&D work partly funded by industry, has succeeded in improving the reliability and rupture safety of pressurized components in the coolant loop. The results achieved in this case form the basis for a new safety concept--"Basic Safety"--accepted by the reactor safety commission. Based on these works, the previously determinative large pipeline breaks taken as a basis for the safety design of light-water reactors, can be generally eliminated from consideration. The investigations on the performance potential and on toughening of previously used non-destructive material-testing methods--which were used to evaluate the safety of components--could also be brought to a conclusion for a broad spectrum of crack detection.

In the project "Nuclear Meltdown" the work on understanding important phenomena and time sequences in the form of limiting investigations (meltdown of a completely uncooled core), has been completed. In the project "External effects", the experimental investigations which led to a general clarification of stress processes of reactor buildings due to aircraft crash and gas-cloud explosion, have been generally concluded.

In the project "Risks and Reliability" the hazard study, phase A, was completed. It established new scales for the hazard analysis of a complicated, large facility and for the first time gave an overall view of the safety level and remaining risks in German nuclear power plants. The results today form an important basis both for additional definition of safety requirements within the licensing procedure and also for future establishment of research goals.

5.8.3 Emphasis of Safety Research

In addition to the results of German hazard studies, world-wide operating experiences and analyses of accidents, especially the analysis of the accident at Three Mile Island (TMI), point up questions requiring more thorough, researched answers in order to permit additional improvements in the facilities.

In the previous program the primary focus was on investigations of large loss-of-coolant-accidents. Due to the subsequent optimizing of the safety features for these extreme stresses, the situation has resulted that less spectacularly beginning disruptions like small coolant leaks and transients in combination with the failure of other systems and faults of operating personnel, have become the dominant risk factor. Another risk reduction thus presumes that beginning accidents are discovered early and consistently, their origins and probable course are recognized and the actual, occurring processes are accurately understood. Only in this manner can in each case the most effective countermeasures be taken to prevent expansion of the malfunction and to limit the consequences of the accident. The need for these studies is also clear if one thinks of the expenses needed to correct the results of any accident. For instance, at present the costs for the decontamination and clean-up at TMI are estimated at about 2 billion DM.

The German hazard study has shown that for nearly two-thirds of all accident sequences which could lead to a core melt-down, human error plays an important role. Consequently, one key to further risk reduction lies in the reduction of possible incorrect actions and behavior of the operating personnel. In this regard questions of personnel training, operating organization and structure of control panels and of operating instructions become very important. Research can make a significant contribution in optimizing the communication system and the man-machine interaction. One has to find the optimum between a thorough automation of protective systems to prevent and limit accidents, and to retain the freedom of action of the operator in the case of unforeseen accidents to recognize inconsistencies in the control of the protective systems and to initiate effective countermeasures.

The theoretical and experimental research work on accident sequences must be increasingly shifted to system disruptions due to leaks and failure of components and subsystems in the cooling loops, which can lead to insufficient core cooling through an unfortunate chain of events.

Once the concept on "Basic Safety" becomes available, continuing investigations on the long-term behavior of the components, especially of those in operating power plants, is of prime interest. It is necessary here, to intensify our knowledge of the safety intervals remaining after long-term operation with its resulting decreased material strength, and in cases of unfavorable stresses, e.g. thermoshocks.

In this regard it is important to refine the remote-controlled non-destructive material testing methods. In spite of the progress in detection achieved in previous projects, a further increase in reliability in the determination of the location and size of even small cracks, is an important task, and in particular, the development of suitable measuring methods shall be pursued.

For a correct evaluation of the remaining hypothetical accidents remaining beyond the designed accidents, one must understand primarily the realistic sequence of a possible core meltdown just before the complete melt-down. Since from the analysis of the TMI accident it has been assumed that first, partial and time-limited core melt processes play a role. From this it follows that in future research work, the realistic sequence of typical core melt accidents must be of primary interest. A better, detailed understanding of these phenomena, especially of the remaining time until containment damage, is also of great importance for planning emergency actions and for any additional measures to reduce the consequences of this type of accident.

In the same regard, a more accurate knowledge of the liberation mechanisms of fission products, their transport and deposition in the containment and their meteorological propagation and settling in the environment is of great importance.

As several findings from the TMI accident have shown, additional experimental and theoretical investigations are needed on this topic.

With regard to the effects of an accident with considerable core damage and with respect to methods of decontamination of facilities damaged in this way, important experiences can be obtained from the work on the TMI-reactor. It is thus intended to obtain a high level of experiences and practical benefit for the FRG through active cooperation in the decontamination measures at TMI.

5.8.4 Important Research Tasks

Disruption of Core Cooling

An investigation of local cooling conditions when flooding the core after large pipe ruptures under consideration of the 3-dimensional thermohydraulic processes in real geometry (2D/3D-emergency cooling project) shall be brought to its conclusion in the large test stand. The investigations on system behavior and core cooling in case of small leaks in the test stands "Loop of Blowdown Investigation (LOBI)" in Ispra and in the test stand "Primary Cooling Loop (PKL)" and in LOFT (Loss of Fluid Test) are being continued.

Containment

Concluding experimental work in the high pressure reactor (HDR) is being conducted to reinforce the validity of extensive model tests on containment stress after a LOCA. Within the framework of expanding the research work, theoretical and if necessary, experimental investigations on potentials for limiting the pressure stress on the containment after hypothetical accidents will be funded. The theoretical and experimental work on stresses and consequent damage due to fires in the containment and the development of methods to reduce hydrogen in the containment after severe accidents, are important research tasks to reduce the number of stresses in hypothetical accidents.

Core Meltdown

The investigations on the realistic sequence of events in a beginning core melt in case of insufficient core cooling and on the realistic sequence of containment destruction due to melting core internals, are important fundamentals for sounding out the risk-reducing potential. In the BETA experiment on the interaction between metal melts and concrete, the testing of models to describe the effect of core meltdowns on the reactor concrete, and in addition the effect on the containment, are being continued.

Component Safety

Important fundamentals for increasing the operating reliability of nuclear power plants are: The establishment of modern rupture-safety strategies and quantification of the safety reserve of reactor components after long-term operation (component safety program, HDR, thermoshock tests) and the development and testing of new systems for a reliable detection of even minute faults in containers and pipelines after long-term operation, and the development of systems for early recognition of flaws and disruptions.

External Effects

The experimental investigations on the stress phenomena on reactor buildings due to aircraft crashes and explosion of gas clouds, and the evaluation of results on improving the available computer models are being concluded and the theoretical and experimental work on stressing important safety components in extremely severe earthquakes is being continued.

Man-Machine Interaction

To optimize the communication system in the man-machine interaction, computer-supported diagnosis aids are being developed for operators for a faster determination of the type, origin and probable course of malfunctions, and investigations on the interfaces of the man-machine relation are being run in normal operation and in case of accident. Training and refresher training for operators is being adapted on the principle of activity analyses and requirement profiles, to the changing requirement.

Fission-Product Transport and Radiation

The improvement of potentials to reduce the radiation exposure of personnel in maintenance and repair continues to be emphasized in the research. The liberation, transport and meteorological propagation and deposition of high-risk fission products in hypothetical accidents requires additional definition. The investigations on the functional reliability of retention systems which reduce the liberation of fission products after accidents, are being continued. Cooperation in the R&D work on TMI decontamination and evaluation of practical decontamination experiences will be continued.

Risks and Reliability

The continued refinement of methods, physical models and data

bases for risk and reliability analyses and the improvement of results and reduction of error intervals in the German Hazard Study are important items in phase B, under consideration of known weakpoints and new research results.

Planning and implementation of all R&D work is proceeding in close international cooperation. In addition to a close multilateral information and experience exchange, e.g. within the frame of OECD, IAEA, EURATOM, our bilateral cooperation with the USA, Japan and France is of great importance. The effect of funding measures performed in an international framework has been successfully improved through work division, concentration of resources in joint projects and liberal exchange of results.

5.9 Radiation-Protection Research

The task of radiation-protection research is to determine the radiation exposure of man due to the various natural and man-made radiation sources, to estimate the hazard connected with this and to develop and improve the necessary technical methods to reduce this radiation exposure.

Radiation protection for employees in nuclear facilities should be improved through administrative measures to increase the ease of repair and maintenance of nuclear facilities. For the analysis of radiation exposure in special mines (especially uranium pits), the measuring technology must be further refined. In addition, the measurement and determination of radiation exposure should be improved through refinements in dosimetry of ionizing radiation (location and personnel dosimetry) and through consumption monitoring. In order to do this, the erection of a central, personal dosage register is needed. In addition, the methods for retention and emission monitoring of radioactive substances should be developed or improved. This should be done through investigations on the retention effect of iodine filters, through upgrading of filter systems for accident conditions, through development of methods for retention of ^3H (tritium), ^{14}C and ^{85}Kr in reprocessing plants and through improving the measuring methods for emission monitoring, especially of ^{14}C and the actinides.

The investigations on the ecological behavior of liberated, radioactive substances shall be continued, like the determination of propagation and deposition parameters in the atmosphere, the migration of radionuclides in the soil and groundwater, the mixing of radioactive waste waters into surface and sea water, the movement of radioactive substances into foods and drinking water, and the analysis of local, regional and global distribution of special, long-lived radionuclides (^3H , ^{14}C , ^{85}Kr , ^{129}I , actinides). In addition, other investigations are being performed on the routes by which radioactive substances get into the body.

The analysis of radiation exposure of the population due to nuclear facilities is being continued. This will be done by improving

measuring methods of environmental monitoring, by preparation of special models for the relevant exposure routes to man, and by analysis of individual and collective doses in normal operation and in accidents. Thus, investigations will be needed on emergency planning and prognoses of future radiation exposure of the population from nuclear facilities.

The handling of special problems of treatment and storage of radioactive wastes is also included in the program on radiation-protection research.

In addition, work will be performed on the biological-medical principles of radiation protection, like investigations of the physical and biochemical primary processes of radiation action, as a function of the radiation quality, investigations on the distribution of radioactive substances in the organism, animal-experiments using small radiation doses, work on the analysis of genetic radiation hazard, investigations on synergistic effects due to the simultaneous effects of radiation and chemical pollutants, performance of epidemiological testing of personnel groups with increased radiation exposure, and the establishment of concepts for specification of limit values for radiation exposure and the intake of radioactive substances by man.

These R&D efforts are being performed in order to retain the high level of radiation protection in the face of the anticipated expansion of nuclear energy use. The program takes into account the fact that protection of the population and of employees from radiation are of equal importance.

The projects of the radiation-protection research program are being performed at the nuclear research centers KfK, KFA, GSF, GKSS and HMI, in federal agencies and institutes (incl. Federal Health Office, Physical-Technical Institute, Federal Agency for Hydrology, Federal Research Institute for Fishery) and by State Institutes, Universities and the GRS.

6. Advanced Reactors

State funds for the first energy research program were concentrated on two advanced reactor lines: The fast, sodium-cooled breeder (SBR or SNR)* and the helium-cooled high-temperature reactor (HTR). The breeder reactor is being funded because it can use natural uranium about 60 times better than in the light-water reactor (over the long term, uranium will be in short supply), and it can be incorporated into the technically-mastered fuel cycle of the LWR. The breeder reactor thus offers the potential for making nuclear energy use in the FRG independent of imports. The HTR is being funded primarily because of the nuclear, high-temperature process heat.

*The designation Fast Breeder reactor is due to the fact that the nuclear fission is done by fast (high-energy) neutrons and not by slow (thermal) neutrons, as in the light-water reactor.

In the interest of a demand-oriented development of new technology, the Federal government tries basically to obtain an early and intensive participation by business. This also requires financial participation appropriate to the level of the development. Thus, since the beginning of 1981, discussions have been underway with the energy utilities on increasing their share of financing the prototype THTR 300 and SNR 300 advanced reactors (previously 1.7% for the THTR 300 and 7.8% for the SNR 300). In discussions with the electric utilities, the Federal government, with the support of the affected State governments, has achieved a fundamental agreement on the financing of the SNR 300.

6.1 High-Temperature Reactors (HTR)

In the FRG the HTR development has been funded intensely by the public, right from the very beginning. This funding included the development and investigation of a number of various HTR concepts and variants. For a long time, generation of electricity was the primary focus. The developments were determined mainly by the producing industry and by the utility companies--which changed from project to project. The result of this HTR development is that in the power class from 15 MW_e to 1350 MW_e, electricity-generating HTR can be used and licensed by business. With this success of technical developments, the market introduction of this power-plant technology has become essentially a matter of energy economics.

Since the mid-1970s, interest has shifted more and more from the electricity-generating HTR to the possibility for using it as a source of nuclear process heat. As a result of preceding developments it turned out that the needed materials, heat cut-out systems and suitable process technology (e.g. for coal gasification to 950 °C) would still have to be developed or improved. In the meantime, progress has been achieved in this matter.

An international overview shows that at the end of the 1970s there was no comparable HTR program outside the FRG. The USA has been conducting a small, State-funded program without concrete project goals, since the 1975 failure of commercialization of the HTR. In France and Great Britain, in spite of experiences with commercial, gas-cooled reactors, the development of HTR-oriented reactors has been terminated. In Japan and the USSR, research work is underway on a smaller scale, with the goal of using nuclear high-temperature process heat. The interest of our Swiss partner in the German HTR program is directed to special HTK components.

Taking stock of the previous high-temperature reactor development leads to the conclusion that a re-orientation of the German HTR development is needed.

The Federal minister for research and technology and the Minister for economics, middle classes and transportation of the State of North-Rhine Westphalia have agreed to find a joint concept for future funding of the HTR development. Pertinent to this is the information conference "High Temperature Reactor" on 1/12/81 and the HTR Status seminar on 9/21/81 in Jülich, and the symposium on potential uses of

high-temperature reactors on 11/13/81 in Dusseldorf.

6.1.1 HTR for Electricity Generation

Based on the good technical results achieved with the 15 MW_e high-temperature reactor (AVR) in Jülich, in 1970 the high-temperature Nuclear Power Plant GmbH (HKG) was formed*.

The task of the HKG is the planning, financing, construction and operation of a 300 MW_e-thorium high-temperature reactor (THTR 300) as a community power plant. The goal is to test the technical and economic suitability of this line of reactors for public electricity generation.

The THTR 300 is a helium-cooled pebble-bed reactor with 750 MW thermal core power-output and 300 MW electric power output (net). The fuel elements contain highly-enriched (93%) uranium.

The THTR 300 is being built by the THTR consortium**. The delivery contract was signed on Oct. 29, 1971.

Originally, the construction time for the THTR 300 was to be 61 months (turnkey power plant on 3/1/77); the costs were estimated to run to 673 million DM complete.

In the meantime, the completion of the primary part has been nearly completed and the pertinent assembly is about 90% done.

Mainly due to the licensing processes and an extension in the construction time from an original 61 months to 151 months at present (i.e. turnkey power plant on 9/1/84), the construction costs have risen to 3 billion DM.

Financing of these increased costs is provided as follows:

*Members of the HKG are:

Community power plant, Weser GmbH, Porta Westfalica (26%)
Elekromark, Kommunales Elektrizitätswerk Mark AG, Hagen (26%)
Vereinigte Elektrizitätswerke Westfalen AG, Dortmund (26%)
Gemeinschaftswerk Hattingen GmbH, Hattingen (12%)
Stadtwerke Aachen AG, Aachen (5%)
Stadtwerke Bremen AG, Bremen (5%)

**Consortium leader, Brown Boveri & Cie AG (BBC), Mannheim; Hochtemperaturreaktorbau GmbH (HBR), Cologne (formerly Brown Boveri/Krupp, Reaktorbau GmbH); NUKEM, Nuclear Chemistry and Metallurgy GmbH, Wolfgang by Hanau.

	Million DM	
BMFT	1,694*	(57%)
NRW	299	(10%)
Increased investment	274	(9%)
Producer	133	(4%)
Operator	90*	(3%)
Loan, guaranteed by state and Federal governments	510	(17%)
	<u>3,000</u>	<u>(100%)</u>

This model presumes that the

- operator raises his ordinary capital from 50 to 90 million DM,
- increase in loan guarantees from 90 million DM to 510 million DM is completed
- discussions on increasing the risk participation agreement between the company and State of North-Rhine Westfalia and between the company and operator, come to a satisfactory conclusion.

Under present financing provisions, the public hand must assume obligations of around 500 million DM for the construction and around 1 billion DM must be set aside for loan guarantees and operating risks. The Federal government endeavors to bring the THTR 300 project in Schmehausen to a successful conclusion. The reactor shall be completed forthwith and taken into operation.

The BMFT has been trying since 1980, together with the producers, to clarify the use of the State-funded HTR technology. In 1980 the Working Committee on the HTR Project study was founded (Arge HTR)**. The BMFT is providing around 8 million DM to support the Arge HTR to BBC/KWU to propose a large HTR (900 MW_e), at the same time representative for the power class of 600 - 1350 MW_e, for a combined generation of electricity and process steam. This reactor should rely mostly on the THTR 300. Right on schedule, the BBC/KWU presented the HTR 900 proposal on 3/31/81. The result of the project study is that the producer and operator both consider the HTR 900 to be technically feasible and fundamentally licensable. In addition, the producer group BBC/HRB confirmed in March 1981 that they can offer high-temperature reactors for all possible applications and for all needed power ranges, to wit:

*Additional participation by a few EVU in the THTR 300 will lead to a corresponding reduction in the BMFT share.

**The "Working Committee HTR Project Study" members are:

Hochtemperaturreaktor GmbH, Hannover; with: Hamburg Elektrizitäts-Werke AG, Hamburg; Hochtemperaturreaktor-Planungsgesellschaft, Düsseldorf; with: Stadtwerke Düsseldorf; Gas-, Elektrizitäts und Wasserwerke, Cologne; Stadtwerke Hannover; Stadtwerke Krefeld, Stadtwerke Munich, Wuppertal Stadtwerke;
Neckarwerke Elektrizitätsversorgungs-AG, Esslingen; Nordwestdeutsche Kraftwerke AG, Hamburg; Preussian Elektrizitäts AG, Hannover; Rhein-Westfälisches Elektrizitätswerke AG, Essen; STEAG AG, Essen; VEBA Kraftwerke Ruhr AG, Gelsenkirchen-Buer; Ruhrgas AG, Essen; Ruhrkohle AG, Essen.

up to	100 MW _e using the AVR principle
100 to	450 MW _e using the THTR 300 principle
450 to	1,350 MW _e using the HTR 900 principle.

The KWU group also was awarded State funded R&D work for the know-how needed for the construction of pebble-bed reactors. In contrast to BBC/HRB, the KWU group concentrated right in the beginning on the application of the HTR for generation of process heat. The KWU group is preparing itself to offer 200 MW_{th} modules through a modification of the AVR principle, which can be combined into larger reactor powers.

These positive statements apply for high-temperature reactors for simple generation of electricity or for linked production of electricity and process steam, for which the greatest part of previous State funding in the amount of 3,000 million DM has been spent.

High-temperature reactors up to 100 MW_e, or of small unit power, are distinguished by reduced power density and passive safety features and thus one can anticipate particularly favorable safety properties. These reactors would come into consideration in the combined generation of electricity and process steam (up to 500 °C), especially for applications in community energy supply companies (remote heat), in chemistry and in coal upgrading. Previously, in these areas there has been no use due to the high expenses.

High-temperature reactors in the medium power range to 450 MW_e do not have the better safety properties of the small power class and are either already too large for the above applications, or are uneconomical in comparison to larger power plants.

High-temperature reactors in the 450 to 1350 MW_e class would in future have to compete with standardized LWR of the 1350 MW_e-class in pure generation of electricity.

From the viewpoint of technical maturation of the HTR technology, according to the producer there is hardly any need for additional funding of R&D. Thus, the energy industry has been called in to make a decision on the use of this available technology. Following projects of the ANR or on the THTR 300 will have to be the responsibility of industry.

6.1.2 HTR for Nuclear Process Heat

The use of the HTR to generate nuclear process heat (950 °C) for coal gasification would make it possible to generate about 1½ times the quantity of product gas from the same quantity of coal, compared to conventional, autothermal coal gasification methods. In the nuclear gasification furthermore, the environmental pollution would be reduced considerably compared to that from conventional gasification methods. With increasing crude energy prices, long-term a cost advantage could result in favor of gasification of hard coal with nuclear process heat.

The Nuclear Process Heat Project (PNP)* has existed since 1975. The project is funded by the BMFT and the State of North-Rhine Westfalia. The original project goal was the rapid erection and operation of a prototype system for nuclear coal gasification.

After 5 years working on the project it is now known that the creation of such a system, whose costs in 1981 were estimated at about 3 billion DM, will require difficult and risky R&D work in the areas of materials, components and gasification methods in the amount of about 1 billion DM. Thus, the material and component development program will undergo a concentration and reinforcement. In the KFA Jülich the development work on the nuclear heat generation system of the HTR will be brought to a conclusion and developments intensified for using the process heat.

Although the nuclear process heat is only a long-term technical possibility for the energy supply, whose commercial implementation is not expected before the next century, here too an early and timely incorporation of business is expected.

6.2 Fast-Breeder Reactors (SBR)

In the FRG the development of breeder reactors has long been the greatest energy research project. This is similarly true for the energy research programs of all large, industrial countries (see tables 3, 4 and 5 in the appendix).

The emphasis of the German SBR development during the term of this project will be on the operation of the pilot plant KNK-II and on the erection of the prototype fast-breeder power plant SNR 300. In addition, preparatory work is being funded for large fast-breeder power plants. The international cooperation begun with Belgium and the Netherlands in the construction of the SNR 300 will be continued. A particularly close cooperation has been initiated with France at the governmental and producer level. Electricity utilities from the FRG (RWE), France (EdF) and Italy (ENEL) have entered into an agreement for the construction of demonstration facilities of large power output. Thus, the experiences from the 250 MW_e-SBR power plant "Phénix" begun in 1974, and of the 1200 MW_e-power plant "Super Phénix" begun in 1976 can be utilized. The construction decision for a demonstration power plant SNR 3 to be erected in the FRG can be made from a technical viewpoint, in the 2nd half of the 1980s.

The German Bundestag (Parliament) has reserved the right to make a decision before initial operation of the SNR 300, based on a recommendation of the Enquete Commission "Future Nuclear Energy Policy".

*Partners: Bergbau Forschung GmbH (BF), Gesellschaft für Hochtemperatur-reaktortechnik mbH (GHT), Hochtemperatur Reaktorbau GmbH (HRB), Kernforschungsanlage Jülich GmbH (KFA) and Rheinische Braunkohlewerke AG (RBW).

The Parliament expects a recommendation of the commission before the summer recess of 1982. In a final report on 7/31/83, the Enquete Commission will work out general recommendations on the use of advanced reactors and of corresponding technologies of the fuel cycle.

6.2.1 Compact, Sodium-Cooled Nuclear Reactor Unit II (KNK II)

The development, construction and operation of the pilot plant KNK at the Karlsruhe Nuclear Research Center served initially for the study of sodium technology. The KNK reached full power for the first time in 1973 and was operated about one year successfully with a thermal oxide core. In the version KNK II, the facility was equipped with a fast UO_2/PuO_2 -core in order to gain additional information about plutonium technology. Through the operation of KNK II since 1977, additional experiences have been gained for the SNR 300 project. In the program term, only the operating and test costs cited in the KfK budget will be incurred.

6.2.2 SNR 300

In 1972 the FRG, Belgium and the Netherlands decided on joint funding of a 280 MW_e prototype power plant with a sodium-cooled fast breeder reactor (SNR 300). The purchaser is the Fast-Breeder Nuclear Power Plant Company mbH (SBK)*. General contractor is the International Sodium-Breeder Reactor Construction Company mbH (INB)**. Purchaser and supplier are supported by research centers in the three countries: Nuclear research center Karlsruhe (KfK); Centre d'Etudes Nucleaires (CEN), Mol; Nijverheid-organisatie TNO, ECN Petten.

The construction of the SNR 300 is based on the R&D work in the participating countries and on the experiences with the 20 MW_e-pilot plant KNK of the KfK.

The costs of the SNR 300 in 1972 were estimated (at turnkey in 1979) to be 1.535 billion DM; present calculation goes up to 5 billion DM (turnkey at the end of 1986). The turnkey erection of the facility and the first supply of fuel, including price increases to that date, are included in this figure. The construction R&D and plutonium supply to be financed domestically in the three participating countries, are not included in these figures (German share 365 and 42 million DM).

*Members of the SBK are: Rheinisch-Westfälisches Elektrizitätswerk AG; S.A. Electronucleaire N.V., Belgium; Samenwerkende Electriciteits Productiebedrijven, Netherlands; Central Electricity Generating Board, Great Britain.

**Members of the INB are: Interatom, Belgonucleaire, Belgium; NERATOOM, Netherlands.

The present financing concept provides for the following participation:

	Million DM	%
BMFT	2,215.0 ¹	44.3
Additional investment	440.0 ²	8.8
Belgium	470.2 ²	9.4
Netherlands	470.2 ²	9.4
Kraftwerk Union	20.0	0.4
Operators:		
-SBK ³	265.5 ²	24.0
-direct contributions of other companies (utilities)	932.1 ⁴	
-indirect contributions of other utility companies	187.0 ⁵	3.7
	<hr/> 5,000.0	<hr/> 100

¹Figure in the 1982 budget, sec. 3005, title 892 11

²Portion of the original total costs of 3.4 billion DM, voluntary amount 333 million DM each.

³Fast-breeder Power Plant Company

⁴Of this amount, just 183 million DM has to be negotiated in 1982.

⁵These indirect contributions are generated through cost offsetting of EVU contributions to other projects of energy research.

With the partial construction approval issued in the autumn of 1981, significant nuclear components were approved. By mid-1982 the last partial construction approval is expected. Then, additional approval requirements for the erection and any resulting delays are no longer expected.

6.2.3 Advanced Breeder Development

In order to broaden the basis of experience, three European EVU decided back in 1972 to erect one fast breeder of 1000 MW, or more in France (Super Phénix) and in Germany (SNR 2). The three EVUs were EdF (France), ENERL (Italy) and RWE (FRG). The international basis of the agreement was expanded to include Belgium and the Netherlands, once the RWE transferred its obligations to the SBK.

Accordingly, the operating company NERSA* was founded for the Superphénix. On the German side, the comparable company for building

*Centrale Nucléaire Européenne Rapide S.A. Participation: EdF 51%, SBK 16%, ENEL 33%.

and operation of the SNR 2 is the ESK*. The shareholders of NERSA and ESK control the financing of both projects in accord with their capital participation. The suppliers are taken into account in accord with the level of participation of their mother countries in the projects, when contracts are issued. The studies on the SNR 2 are financed by the SBK/ESK. The continuing work is concentrated primarily on the refinement of the fuel cycle, on safety and reliability of systems. The development and long-term testing of components and materials plays an important role in this. Producers and research institutes are cooperating on this in French, Belgian and Dutch facilities.

The governments of France and the FRG in May 1976 created the foundation for a more intensive cooperation with the research centers and producing industry; this cooperation is specified in detail by a work contract among the participants. The broad European cooperation agreed upon in this manner is still being expanded through numerous international contacts, e.g. with USA, Japan, Great Britain.

6.2.4 Breeder Fuel-Cycle

A closed fuel cycle is a necessity for the fast-breeder--without this the excellent uranium utilization cannot be achieved. During the program term therefore, work will continue on the adaptation and refinement of the technology of the LWR fuel cycle for the special demands of breeder reactors. This work can be enhanced by intensifying the cooperative agreement concluded with France in 1976. This work is being performed in the nuclear research center, Karlsruhe.

6.3 Research Reactors

Research reactors can be used for a broad spectrum of scientific and technical investigations. Research reactors are thus being operated throughout the world, both in industrial and in developing countries, including many nations where a commercial utilization of nuclear engineering to generate power is not yet in sight. Many of these reactor systems are operated with highly-enriched uranium (93% U-235). Within the framework of the International Evaluation of the Nuclear Fuel Cycle (INFCE), the conclusion is widely drawn that to prevent the risks of proliferation, the operation of research reactors with highly enriched fuel should be avoided if possible. Estimates show that many research tasks can be solved by using only ca. 20% fuel enrichment in research reactors. The creation of such systems presumes however, the availability of new fuels and fuel-element production techniques, in addition to changed reactor systems. During the INFCE evaluation, the Federal government began a corresponding fuel development program.

*European Fast-Breeder Nuclear Power Plant Company mbH.
Participation: SBK 51%, EdF 16% and ENEL 33%.

This fuel and fuel-element development must be supplemented by the development and demonstration of an appropriate reactor system. In the FRG there is a series of research reactors whose capabilities and safety level have been improved through retrofitting. This type of retrofitting is currently intended for the BER 2 research reactor in Berlin. These systems will still have to be operated with highly-enriched uranium fuel, since a retrofitting to this new type of fuel would result in excessive costs. On the other hand, in the FRG there are no plans to build a new research reactor until further notice. Thus, the interest of Indonesia in this type of system provided a good opportunity to demonstrate this technology. Intentions are to build this type of new research reactor, together with Indonesia and the development of this new research reactor type will be funded to a certain extent by R&D funds.

A completely new technique to permit similar experiments as on research reactors, is opened up by the high-power proton accelerators to generate high neutron fluxes (spallation sources). The potential for erection of such a spallation source at the KFA Jülich is being examined.

7. Controlled Nuclear Fusion

Controlled nuclear fusion is designed to use the energy from the nuclear fusion of heavy hydrogen nuclei into helium. In order to set this process in motion and to contain it, sufficiently dense plasma must be generated at extremely high temperatures (over 100 million degrees) for a sufficiently long time. The starting materials for this process are deuterium (from water) and tritium, which has to be obtained via neutron reactions from lithium. Deuterium and lithium are abundant on the earth, so that nuclear fusion could open up a new energy source which has a large potential similar to the breeder. In contrast to this reactor, fusion potential has not yet been demonstrated. This is due primarily to the enormous difficulties existing in the development of technologies to master hot plasmas and in our understanding of the physics of hot plasmas. Although a great worldwide research effort has been underway in this area for about 25 years, and although in recent years very large advances in physics have been made, a demonstration reactor--if we really succeed in building one--cannot be expected before the end of this century. Commercial useage of fusion energy is accordingly not expected until sometime after the year 2000.

A fusion reactor, according to present knowledge, will have safety and environmental problems like present fission reactors or other facilities for energy generation. But they are of a different, partly new type: For example, the radioactive inventory of a fusion reactor will be less than that of a light water reactor or a breeder, but large quantities of radioactive tritium will be converted, or large quantities of radioactive structural materials will have to be dismantled at frequent intervals and stored safely. It is important that the recognized safety and environmental problems of fusion

be taken into account at an early date in the research programs, since their solution might take a long time.

A fusion of hydrogen nuclei and thus the desired release of energy only occurs when the plasmas are held together at appropriate temperatures at sufficient densities for a sufficiently long time. If these conditions are met (so-called Lawson criterion), the fusion process is maintained by the liberated energy itself: the plasma has then "ignited." This goal is sought in two fundamentally different ways: Inertial fusion and fusion with magnetic occlusion. The main efforts on fusion worldwide, and particularly in Europe, are directed at magnetic occlusion. There are several concepts for this, of which Tokamak is the one which has been investigated most intensively. In addition, there are the reflector device, the reversed-pinch and the Stellarator. The FRG has achieved worldwide recognition for its work on the Tokamak and is the international leader in the Stellarators.

In the past, fusion research had concentrated mainly on the investigation of difficult and complex plasma-physical problems with the goal of recognizing regularities which will lead to ignition of the plasma under controlled conditions. This goal has not yet been reached and requires additional, sometimes larger-scale experiments. Besides the physical investigations, it is now necessary to be concerned more than before with the technological problems connected with fusion. Among these are material questions, tritium handling or superconductor engineering. Both areas--plasma physics and technology--must work together to order to reach the goal of a fusion reactor.

Since the funds needed for this are large, in spite of its distance from final completion, and in some cases are beyond the means of individual European countries, a joint fusion research program was developed in Europe within the frame of Euratom. Sweden and Switzerland have joined the research program.

The European research program was restructured in the summer of 1981 and studied by a commission of independent experts. Thereafter, in 1982 to 1986 it will concentrate on the refinement of the Tokamak and investigate the alternatives of Stellarator and the reversed-pinch concept; furthermore, smaller efforts on inertial fusion are intended. The long-term goal of the program--no earlier than the turn of the century--is the construction of a fusion demonstration reactor (DEMO), which need not necessarily be a Tokamak. The way to the goal should lead from the Tokamak large experiment JET (Joint European Torus) under construction now in Culham (Great Britain), to only one other large experiment, the Next European Torus (NET). Planning for NET should begin soon. But the groundbreaking is not expected before 1990, since significant results of the JET experiments will be needed for the NET concept.

The planning of NET also serves as an indication for the definition of an extensive and coherent fusion-technology program which will include primarily the following points: Superconductor engineering, tritium handling, remote control, breeder mantle technology and material development and environmental and safety questions.

Through the development steps JET-NET-DEMO, not all problems can be handled from the spheres of pure plasma physics and the technological developments. Thus, supplemental, larger experiments are needed in the member countries.

In the FRG there are primarily:

- the Tokamak experiment ASDEX of the IPP, which will examine in particular the plasma heating methods, purity of plasma through diverters and fuel replenishment. It is planned to expand this experiment (ASDEX upgrade) so that in the second half of the 1980s, the plasma maintenance and the different zones of the plasma can be investigated on the necessary scale.
- the Tokamak experiment TEXTOR of the KFA which should clarify important questions of the plasma-wall interaction. An intensification of the heating power is planned in coming years to expand this instrument.
- the test stand TOSKA of the KfK, in which large, KfK-developed superconductive magnetic coils will be tested, together with the development of superconducting technology.
- the Stellarator experiment Wendelstein VII-A of the IPP which will help in the development of an alternative to the Tokamak. It is intended by the mid-1980s to expand this experiment to the Wendelstein VII-AS. The facility will then have an enlarged plasma diameter and be of modular design.

The increasing importance of technology development should take into account that the Karlsruhe nuclear research center is increasingly concerned with technological problems as far as the construction of corresponding, large experimental facilities. Again, an early participation of industry in this area is desired to a certain extent.

Besides IPP, KFA and KfK, smaller nuclear fusion activities will be performed in the GSI and HMI.

Moreover, several universities are handling plasma physics problems in cooperation with the programs of the centers. The DFG has a program on "Fusion Oriented Plasma Physics."

On an international scale, the existing cooperation with EURATOM will be continued. In addition, EURATOM is cooperating with the IEA and IAEA.

Table 1: Total Expenditures for Energy Research and Development within the Framework of the Energy Research Program (basis: Federal budget 1982)

	1981	1982	1983	1984	1985
2.1.1 Household and small consumers	25	13	17	20	23
2.1.2 Industry	23	41	43	47	55
2.1.3 Transportation	-	-	-	-	-
Extensive system investigations, energy supply concepts	2	10	11	11	16
System technology	5	8	11	13	17
2.1 Applied technology for the end user	45	72	82	91	111
2.2.1 Waste heat utilization and remote heat	49	44	48	54	68
2.2.2 Energy storage	16	16	16	16	16
2.2.3 Hydrogen and remote energy	25	27	35	35	35
2.2 Techniques and methods to generate secondary energy	90	87	99	105	119
2. New technologies for rational use and generation of energy	155	159	181	196	230
3.1 New power plant and firing technology	68	93	125	152	173
3.2.1 Coal gasification	25	166	300	456	672
3.2.2 Coal liquifaction	71	123	138	148	163
3.2 Coal upgrading	96	289	438	604	672
3.3 Deposit exploration, mining technology, separating	139	96	99	105	109
3.4 Underground gasification	3	9	7	7	4
3.5 New methods of extraction, processing and storage of liquid hydrocarbons and natural gas	46	103	108	98	100
3. Coal and other fossil fuels	352	590	777	966	1221

Table 1 (continued)

	1981	1982	1983	1984	1985
4. Systems and concepts					
4.2 Heat from the sun	31	27	28	28	28
4.3 Electricity from solar energy	23	17	17	19	19
4.4 Energy from biomass and wastes	25	58	59	60	61
4.5 Wind energy	9	13	14	15	15
4.6 Geothermal energy	48	29	29	29	29
4. New energy sources	12	13	15	13	15
5.1 Natural uranium supply and conversion	148	157	162	164	166
5.2 Uranium enrichment	7	11	12	12	12
5.3 Fuel element production	107	121	127	134	132
5.4 Detoxification with reprocessing	8	10	16	17	18
5.5 Other neutralization techniques					
5.6 Removal of nuclear facilities	283	313	264	267	270
5.7 Fissionable materials flux control	10	11	12	15	18
5.8 Nuclear safety research	122	161	163	165	151
5.9 Radiation protection research	30	32	34	34	34
5. Nuclear fuel cycle and reactor safety research	567	659	628	644	635
THTR 300	118	143	157	150	165
HTR refinements	143	155	126	86	61
6.1 High-temperature reactors	261	298	283	236	226
SNR 300	233	230	245	299	362
Advanced breeder development	142	149	151	162	220
6.2 Breeder reactors	375	379	396	461	582
6.3 Research reactors	18	24	14	10	-
6. Advanced reactors	654	701	693	707	808

Table 1 (continued)

7.	Controlled nuclear fusion Program (total)	1981	1982	1983	1984	1985
		94	99	100	112	120
		1970	2365	2541	2789	3180
		Contained therein are sums from:				
	-institutional funding (research centers)*	674	703	647	645	630
	-BMI (radiation protection research & nuclear safety features)	22	56	59	59	59
	-BMW ⁱ	97	107	217	367	567

* of this amount, 10% comes from states having research centers.

Table 2: Overview of the Development of Expenditures in the Energy Sector (to be updated)

	1972	1973	1974	1975	1976	1977	1978	1979	1980
I. Nuclear energy research	789	831	924	1079	1004	952	1012	1094	1199
II. Non-nuclear energy research	10	18	110	222	233	267	476	584	614
III. Fusion research	57	64	76	80	85	71	75	95	94
R&D total	856	913	1110	1381	1322	1290	1563	1773	1907
IV Coal assistance ¹	1240	1693	1965	2088	2707	3571	5273	6875	6303
V. 4.35 billion DM energy conservation ⁴ program (50% for Federal and state)	-	-	-	-	-	-	830	880	880
VI. Surcharges for remote heat (ZIP) ²	-	-	-	-	-	20	60	180	180
VII. Other assistance ³	-	-	-	10	29	52	68	112	135
Total nuclear/non-nuclear (without fusion)									
I/(II+IV+V+VI+VII)	0.63	0.49	0.45	0.46	0.34	0.24	0.15	0.13	0.15

Notes: The irregular relation of expenditures for nuclear to non-nuclear research reflects the irregular flow of funds to a few large projects.

¹ Includes coking coal assistance, investment assistance for environmental protection, social assistance for miners, unemployment assistance; figures estimated for 1979 and 1980.

² Figures estimated for 1979 and 1980

³ Market introduction program (BMWi), advice and consultation (BMWi), financing measures (BML), surcharges as per Art. 4a, Investment law (BMF).

⁴ Incl. estimated decreased receipts from tax write-offs.

Table 3: Test Reactors with "Fast" Reactor Core

Reactor	Country	Operating begin/end	Thermal power MW _{th}	Electrical power MW _e
EBR-1	USA	1951/1963	1.2	0.2
BR-1	USSR	1955/1956	0	-
BR-2	USSR	1956/1958	0.1	-
BR-5	USSR	1958/1971	5	-
DFR	Gt. Brit.	1959/1977	60	14
Enrico Fermi	USA	1963/1971	200	66
EBR-II	USA	1965	62.5	20
Rapsodie	France	1967	20 (after 1970; 40 MW _{th})	-
BOR-60	USSR	1969	60	12
SEFOR	USA	1969/1972	20	-
BR-10	USSR	1973	10	-
KNK-II	FRG	1977	58	20
JOYO	Japan	1978	100	-
FFTF	USA	1980	400	-
FBTR	India	under constr.	42.5	12.5
PEC	Italy	under constr.	116	-

Table 4: Prototype Power Plant with Fast Reactor Core

Reactor	Country	Operation began	Thermal power MW _{th}	Electrical power MW _e
BN-350	USSR	1973	1000	125*
Phénix	France	1973	563	250
PFR	UK	1974	600	250
SNR-300	FRG, Belg. Neth.	1985 (under const.)	760	327
Clinch River	USA	Component produc- tion		
MONJU	Japan	Planning	715	210
FBR-500	India	Studies	1250	500

*Besides the electricity generation, the BN-350 will be used for desalination of sea water (80,000 t/d purified water).

Table 5: Breeder Demonstration Power Plants

Reactor	Country	Operation begins	Thermal power MW _{th}	Electrical power MW _e
BN-600	USSR	1980	1470	600
Superphénix I	France	1983/84, under construction	3000	1200
Superphénix II	France	in planning	4000	1500
BN-800	USSR	in planning	2100	800
BN-1600	USSR	in planning	4200	1600
CDFR	Gt. Br.	Studies	3250	1250
SNR-2	FRG, Belg. Neth, Italy, France	Studies	3750	1300
			-	1000

Project Participants in the Energy-Research Field

1. Reactor Safety Company (GRS), mbH, Cologne, Research Management Division, 12 employees
2. Nuclear Research Facility, Jülich GmbH, project management for non-nuclear research (PLE), 78 employees
3. Nuclear Research Facility Jülich, GmbH, development of the high-temperature (HTR) system, 10 employees
4. Nuclear Research Center, Karlsruhe GmbH, University research on the nuclear fuel cycle/shut-down of nuclear facilities, 4 employees.

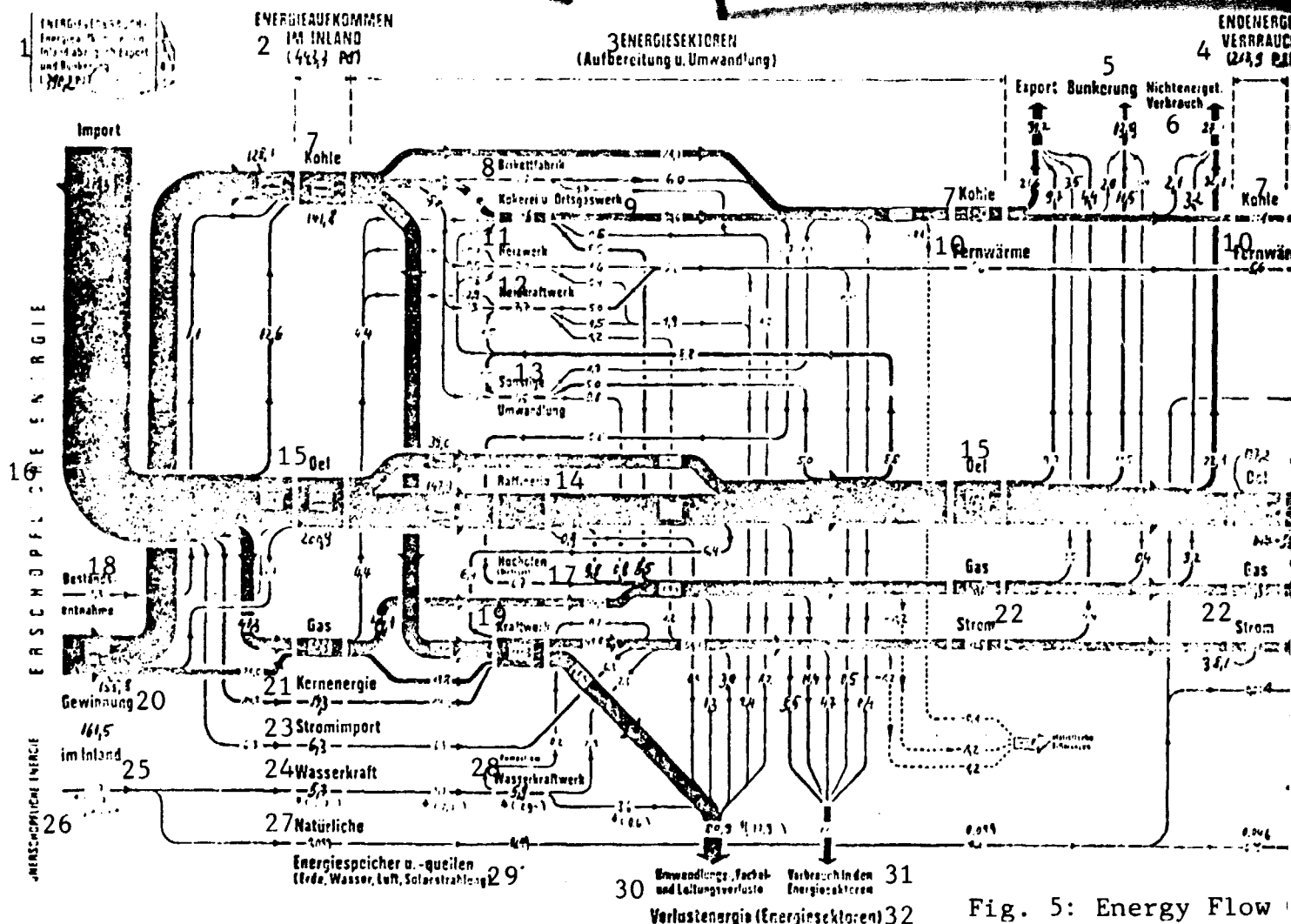


Fig. 5: Energy Flow

Key: 1-energy consumption, energy resources, domestic minus export and storage 2-domestic energy resources 3-energy sectors (processing & conversion) 4-end-energy consumption 5-storage 6-non-energetic consumption 7-coal 8-briquette factory 9-coking & local gas plant 10-remote heat 11-heating plant 12-heating plant 13-other conversion 14-refinery 15-oil 16-finite energy sources 17-blast furnace 18-energy stocks 19-power plant 20-generation 21-nuclear energy 22-electricity 23-electricity import 24-hydroelectric 25-renewable energy 26-renewable energy 27-natural 28-hydropower plant 29-energy storage & sources (gravel, radiation) 30-conversion [illeg.] & pipeline losses 31-consumption in the energy sectors (energy sectors) 32-consumption in the energy sectors 33-consumer sectors 34-industry 35-transportation 36-useful energy consumers 39-energy loss (consumer sectors)

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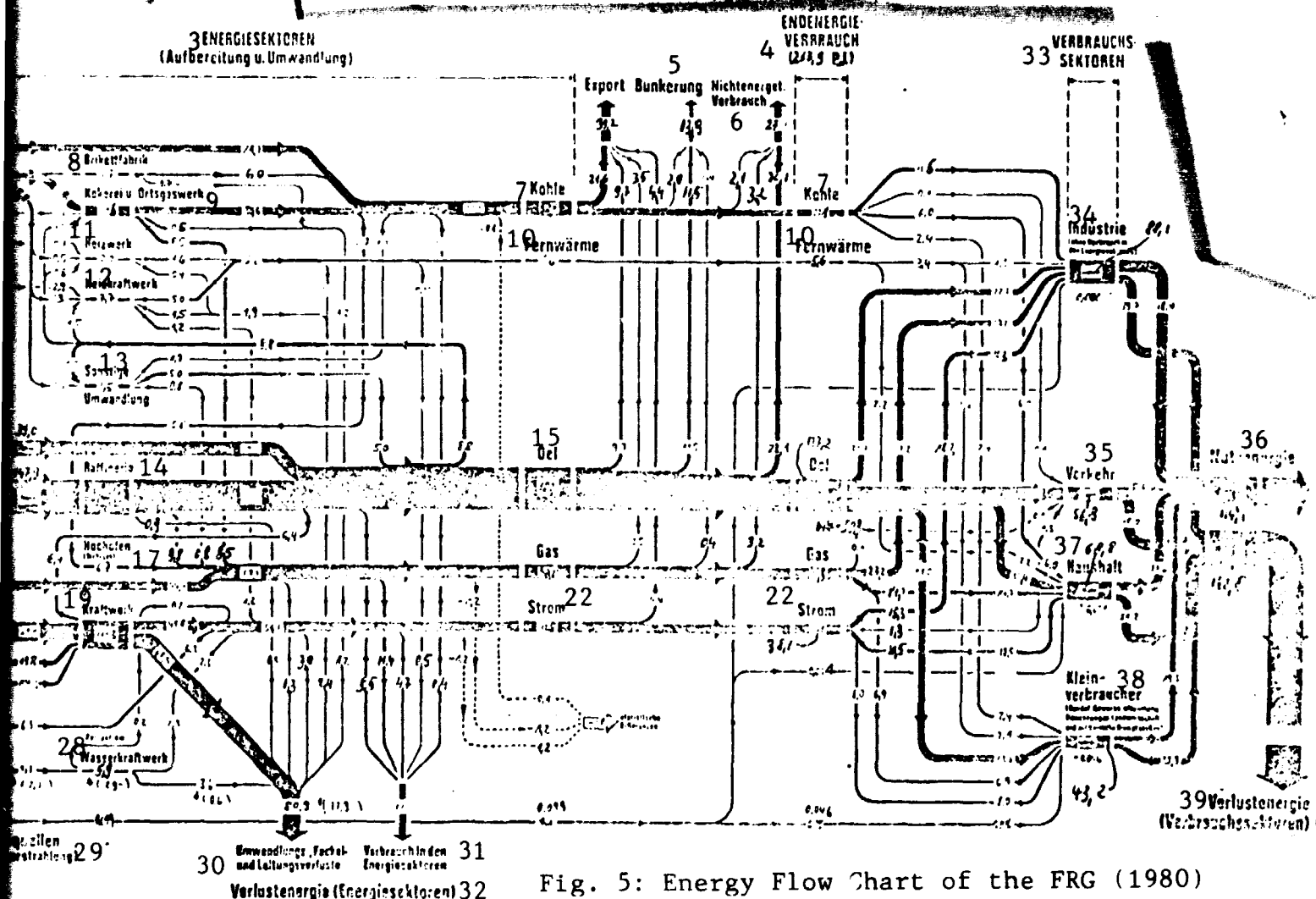


Fig. 5: Energy Flow Chart of the FRG (1980)

Energy resources, domestic minus export and storage 2-domestic energy resources & conversion) 4-end-energy consumption 5-storage 6-non-energy consumption -coking & local gas plant 10-remote heat 11-heating plant 12-heating power -refinery 15-oil 16-finite energy sources 17-blast furnace 18-depletion of stocks 21-nuclear energy 22-electricity 23-electricity import 24-hydro-power 25-domestic al 28-hydropower plant 29-energy storage & sources (ground, water, air, solar leg.) & pipeline losses 31-consumption in the energy sectors 32-energy loss sectors 34-industry 35-transportation 36-useful energy 37-household 38-small consumer sectors)